Government of Canada
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Government of Manitoba

Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion

Canada Manitoba

Canada-Manitoba Mercury Agreement

ERRATUM

Page 39 Table 4.7

The fourteenth line of figure should read

(Population)	Blood	284	272	12	1

CANADA-MANITOBA
AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

ANNUAL REPORT
FOR
THE PERIOD
April 1, 1983 to March 31, 1984

Canada Manitoba

Canada-Manitoba Mercury Agreement

January, 1985

The Honourable Suzanne Blais-Grenier,
Minister,
Environment Canada,
28th Floor,
Les Terrasses de la Chaudiere,
HULL, Quebec.
K1A 0E7

The Honourable Gerard Lecuyer,
Minister,
Department of Environment and
Workplace Safety and Health,
Room 156, Legislative Building,
WINNIPEG, Manitoba.
R3C 0V8

My dear Ministers:

I am pleased to present the second Annual Report of the Canada-Manitoba Agreement on the Study and Monitoring of Mercury in the Churchill River Diversion.

This report details the progress of the Agreement for the fiscal year ending March 31, 1984.

Dale Kimmett

Mr. D. Kimmett,
Co-chairperson,
Steering Committee,
521-269 Main Street,
WINNIPEG, Manitoba.
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RÉSUMÉ POUR LA DIRECTION

Voici le second rapport annuel de l'Accord signé le 10 mars 1983. Un Comité technique consultatif, composé de huit membres, a été nommé en avril 1983; toutefois, deux autres membres ont été nommés, et en février 1984, le total était de 10 membres. On a engagé un coordonnateur de l'accord en juin 1983.

Dans le cadre de l'accord, on comptait six projets à coûts partagés en 1983-1984, dont cinq avaient également été financés en 1982-1983. Le projet 2.4, Étude limnologique, a été financé pour la première fois. Sur les six projets, cinq ont progressé appréciablement; l'exception est le projet 4.1 Sensibilisation du public. Les trois projets, sans partage de frais, ont tous été en pleine activité en 1983-1984. Jusqu'à présent, voici les résultats des travaux qui ont été terminés dans le cadre de l'accord:

1. Les mesures de concentration de mercure dans l'eau et les sédiments de l'aire faisant l'objet de l'étude ont révélé des niveaux au-dessous des limites de détection dans le cas de l'eau et légèrement au-dessus de ses limites dans le cas des sédiments (Projets 1.1 et 1.3).

2. Le projet 1.3 a révélé que les niveaux de mercure dans le poisson étaient nettement plus élevés aux régions inondées par rapport à celles qui ne l'étaient pas, et que les matières organiques inondées constituaient un facteur qui a contribué sensiblement à l'accroissement des niveaux de mercure dans le poisson. Les résultats ont également fait connaître que la teneur moyenne en mercure des sols qui ont été inondés ultérieurement était environ de trois fois celle du fonds des lacs pré-existant. Plus l'aire des sols nouvellement inondés était vaste, plus la hausse relative de la quantité de mercure était élevée. Toutefois, la situation n'a révélé aucune diminution progressive du mercure du sol.

3. Dans le cadre du projet 2.1, on a mené un certain nombre de travaux différents au cours des dernières années afin de pouvoir mieux définir les conséquences des matériaux organiques inondés sur les niveaux de mercure dans le poisson. Certains travaux précédents, aux termes de ce projet, avaient révélé, parmi d'autres choses, que de la mousse ou de la tourbe nouvellement

ajoutée stimulait constamment la bioaccumulation de l'isotope radioactif du mercure dans le poisson. Parmi les travaux de 1983, deux visaient à déterminer si des variations s'étaient produites dans un délai d'un an par suite des traitements de mousse. Les travaux ont confirmé que les résultats étaient analogues. Un autre genre de traitement consistait à remuer le fond d'un lac qui avait été inondé six ans plus tôt. Au cours des travaux de 1982, le fond de ce lac n'avait pas réagi différemment par suite des mesures de contrôle utilisées. Toutefois, on a trouvé qu'après avoir remué le fond, il était maintenant en mesure de stimuler la bioaccumulation de mercure radioactif. Au cours d'un autre traitement, lorsqu'on a ajouté des sédiments en même temps que de la nouvelle mousse, il semblait se produire un effet synergique à l'endroit de la bioaccumulation de mercure radioactif.

4. Les matériaux organiques inondés ajoutés au lac se répercutent sur les niveaux de mercure dans le poisson à la suite des effets produits sur les taux de méthylation. Des travaux sur le terrain (Projet 1.3 et 2.4) ont révélé que les taux de méthylation étaient beaucoup plus élevés aux emplacements situés au-dessus d'un sol inondé qu'à ceux situés au-dessus de sédiments pré-existants à l'écart du littoral. Il semble également que la situation présente un caractère saisonnier; les taux étant plus élevés vers le milieu de l'été, mais plus bas vers la fin de l'été. Selon certaines données préliminaires, les taux de déméthylation étaient plus élevés au-dessus des sédiments à l'écart du littoral qu'au-dessus des sédiments inondés près du littoral. Les taux de métilation s'accroissent en fonction de l'ampleur de l'inondation et l'ordre des taux de métilation est en bonne corrélation avec la quantité de mercure dans le poisson qu'on a prélevée à ces emplacements en 1982.

5. Les observations résultant des travaux en laboratoire qui ont été menés dans le cadre du projet 2.3 concordent avec les résultats provenant des travaux sur le terrain propres à d'autres projets. On a remarqué que les taux de méthylation microbiennes du mercure ont augmenté par suite de changements environnementaux récents. Les travaux dans le cadre du projet 2.3 révèlent également que la production nette de méthyl-mercure au cours d'une période de temps donnée est plus élevée dans des conditions d'anaérobie que dans des conditions d'aérobie, et que les bactéries de méthane jouent un rôle

important dans la méthylation du mercure dans des milieux d'anaérobie où les éléments nutritifs organiques abondent.

6. Une des façons dont le mercure peut pénétrer dans la chaîne alimentaire aquatique est par la voie de communautés benthiques. L'analyse des travaux qu'on a amorcés en 1981 au sujet du mercure dans les communautés benthiques (Projet 2.2) se poursuit.

7. Les niveaux de mercure dans le poisson continuent d'être contrôlés dans le cadre des projets 3.2 et 3.3. L'analyse du poisson, dans le cadre du programme d'étude à Southern Indian Lake et Isset Lake, révèlent que nonobstant la continuation du déclin des niveaux de mercure dans le corégone échantillonné, ils sont toujours au-dessus des niveaux antérieurs à la captation des eaux. Les niveaux de mercure dans le poisson prédateur, comme dans le brochet et dans le doré, n'ont pas diminué et ce, cinq ans après la captation des eaux. Ces résultats concordent avec ceux qui proviennent de l'échantillonnage commercial propre aux espèces de ces lieux. Cette année, on a amorcé un programme d'étude pour mesurer les niveaux de mercure dans le poisson d'autres lacs qui se situent le long ou près de la dérivation.

8. Santé et Bien-être Canada continue son programme de contrôle du mercure chez les autochtones de la région étudiée. Les résultats de son programme de 1983-84 (du 1er juillet 1983 au 31 octobre 1984) figurent au tableau 4.5. Parmi les autochtones testés, une femme présentait des niveaux de mercure exceptionnellement élevés selon l'échantillon de cheveux étudié. Santé et Bien-être se charge de la tester à nouveau.

9. Les résultats découlant d'un nombre de projets propres à l'Accord suggèrent que les effets de matériaux organiques et de matériaux de rivage usés par l'érosion ont stimulé la bioaccumulation du mercure dans le système. L'objet du projet 2.4 est d'obtenir une estimation concernant la durée probable de ces effets. Une étude des paramètres, soit les concentrations d'oxygène et de sédiments, nous fera connaître de quelque façon si le système s'écarte de l'étape post-captation. Dans la négative, l'étude peut vouloir signifier qu'un état à long terme à peu près constant pourrait continuer pendant un certain temps, ce qui indiquerait que le problème du mercure continuera d'exister.

EXECUTIVE SUMMARY

This is the second annual report since the signing of the Agreement on March 10, 1983. An eight member Technical Advisory Committee was appointed in April 1983, with an expansion to ten members in February 1984. An Agreement Coordinator was hired in June 1983.

There were six cost shared projects funded under the Agreement in 1983/84, five of which had also been funded in 1982/83. Project 2.4, Limnological Survey, was funded for the first time. Good progress was made on five of the six projects, the exception being Project 4.1, Public Awareness. The three non cost shared projects were all active in 1983/84. Results of the work completed under the Agreement to date include:

1. Measurements of the mercury concentrations in the water and sediments of the Agreement study area have shown levels below the detection limits for water and slightly above the detection limits for sediments (Projects 1.1 and 1.3).

2. Project 1.3 showed that the fish mercury levels were distinctly higher at flooded sites as compared to unflooded sites, and that flooded organic material was an important contributing factor in the increased mercury levels in the fish. The results of this project also showed that the average mercury content of the soils that were subsequently flooded were about three times that of the pre-existing lake bottoms. The larger the area of newly flooded soils, the greater the relative increase in the amount of mercury. However any depletion of this soil mercury was not demonstrated.

3. Under Project 2.1, a number of different experiments have been conducted over the last few years to better define the effects of flooded organic material on fish mercury levels. Previous experiments under this project have shown, amongst other things, that newly added moss - peat consistently stimulated the bioaccumulation of the radioactive isotope of

mercury in fish. Two of the 1983 experiments were designed to determine if any variation occurred within one year within the moss treatments. The results showed that they replicated well. Another treatment involved stirring a lake bottom which had been flooded six years ago. In the 1982 experiments this lake bottom had been giving no different response from the controls used. However it was found that after it had been stirred, it now had the ability to stimulate the bioaccumulation of radioactive mercury. In another treatment when sediment was added along with new moss, there seemed to be a synergestic effect with respect to the bioaccumulation of radioactive mercury.

4. The flooded organic material added to the lake affects mercury levels in fish by its effect on increased methylation rates. Experiments in the field (Project 1.3 and 2.4) have shown that methylation rates were much higher at sites located over flooded soil than those over off shore pre-existing sediments. There also seems to be a seasonality to this pattern, with rates being higher in the middle of summer and lower in late summer. Some preliminary data has shown that the demethylation rates were higher over the offshore sediments than over the near shore flooded sediments. Methylation rates increased with the extent of flooding and this order of methylation rates correlated very well with the amount of mercury in the fish collected at these sites in 1982.

5. Observations from the laboratory experiments conducted under Project 2.3 are in good agreement with the results from the field experiments of other projects. These observations include the fact that rates of microbial mercury methylation are increased as a result of the recent environmental changes. Project 2.3 experiments also indicated that net methyl mercury production in a given period of time is greater under anaerobic than under aerobic conditions, and that methane bacteria may play an important role in mercury methylation in anaerobic environments where organic nutrients are abundant.

6. One of the ways in which mercury can enter the aquatic food chain is through the benthic communities. Analysis of the work conducted in 1981 on mercury in the benthic communities (Project 2.2) is continuing.

7. Mercury levels in fish continued to be monitored under Projects 3.2 and 3.3. Analysis of fish taken in the fish survey program from Southern Indian Lake and Issett Lake showed that while the mercury levels of the whitefish sampled continued to decline, they were still above pre-impoundment levels. The mercury levels in the predatory fish such as northern pike and walleye have not decreased 5 years after the impoundment. These results are consistent with the commercial fish sampling results for these species in these locations. A fish survey program to measure mercury levels in fish from other lakes along or near the diversion began this year.

8. Health and Welfare Canada continued their program of mercury monitoring of the native people in the study area. Results of their 1983/84 program (from July 1, 1983 - October 31, 1984) are presented in Table 4.5. Of those tested, one woman had unusually high mercury levels as measured by her hair sample. She is being retested by Health and Welfare Canada.

9. Results from a number of Agreement projects suggests that the impacts of organic material and eroded bank material have stimulated mercury bioaccumulation in the system. The objective of Project 2.4 is to obtain an estimate of how long these impacts may continue to last. Looking at parameters like oxygen and sediment concentrations as was done in 1983, will provide an indication of whether the system is evolving away from the post impoundment stage. If not, then this might mean that a long term quasi-steady state might persist for some time, indicating that the mercury problem will continue.

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CHAPTER 1. INTRODUCTION

1.1 Year in Review

All six of the cost shared projects scheduled to be underway in 1983/84 were undertaken, namely Projects 2.1, 2.3, 2.4, 3.3, 4.1, and 4.2. Expenditures were incurred in five of these projects, the exception being Project 4.1. In addition the three non funded Agreement projects, namely Projects 1.1, 3.2, and 3.4, were also active in 1983/84. A discussion of the progress made on each of the Agreement projects is presented later in this report.

On November 3, 1983 a "Work-In-Progress" meeting was held. The purpose of this meeting was to provide a forum whereby the project leaders could present their findings to date and where all Agreement participants would be given the opportunity to discuss these findings. In addition to the Agreement participants there were two invited guests at this day long meeting. Mr. C. Gillespie, legal counsel for the Northern Flood Committee, was invited to attend because of his strong interest and knowledge of the study area of the Agreement. He was also the luncheon guest speaker. Dr. J. Rudd, Fisheries and Oceans, was invited to attend because of his acknowledged expertise in the study of MERCURY[1] in the environment. This meeting was very successful in achieving its purpose, and as a result another "Work-In-Progress" meeting will be scheduled in 1984/85.

A number of administrative and financial arrangements were introduced. Financial Guidelines and Project Report Guidelines were approved by the Steering Committee. Project Information Updates were also introduced. These updates provide a brief (approximately two page) summary of the relevant information concerning each project, such as project objectives, project leader's name, expenditures incurred to date, and principal findings. These updates are prepared approximately twice a year and copies of each update are circulated to all Agreement participants.

1 Throughout this report, whenever a "technical" word appears for the first time, it will appear in capital letters. The meaning of these "technical" words will be found in the glossary at the end of the report.

1.2 Administrative Arrangements

In April 1983, the Steering Committee appointed an eight-member Technical Advisory Committee. The federal government is represented by two members each from the Department of Environment, and the Department of Fisheries and Oceans. The provincial government is represented by two members each from the Department of Environment and Workplace Safety and Health, and the Department of Natural Resources. In February 1984, two additional members were appointed to this committee, one each from the federal Department of Health and Welfare and the provincial Department of Health. The names and addresses of all ten members are given in Appendix A.

The Technical Advisory Committee met three times during 1983/84 - in April 1983, November 1983, and February 1984. The purpose of the April meeting was to convene the group and discuss the role this committee would play in the implementation of the Agreement. In November 1983 the committee met to discuss a number of items such as the format and distribution of Agreement reports, and the best approach to follow in undertaking Project 1.2 in 1984/85. The February 1984 meeting was directed at examining the progress of each of the Agreement projects, evaluating them in terms of their fulfillment of the Agreement objectives, and making recommendations regarding the direction to be followed for these projects in 1984/85.

The Steering Committee met a total of seven times during 1983/84. Mr. N. Brandson, Environment and Workplace Safety and Health, was the Chairperson of the Steering Committee for 1983/84. The names and addresses of all members of the Steering Committee are also given in Appendix A.

On June 27, 1983, in accordance with section 3(6)(e) of the Agreement an Agreement Coordinator was hired, in the person of Ms. L. McKerness, to manage and coordinate the implementation of the Agreement projects.

1.3 Financial Arrangements

The introduction of Financial Guidelines facilitated the prompt payment of claims submitted under the Agreement. Complete financial records were maintained for purposes of possible future audits. Table 1.1 shows the total cost shared expenditures incurred under the Agreement in 1983/84.

1.4 Agreement Projects

The remainder of this annual report contains a discussion of the progress made in 1983/84 on each of the Agreement projects. Work on these projects is ongoing. Even in the case of those projects for which all the field data has been collected, analysis and interpretation of the results is still continuing. Because of the dynamic status of all projects, new hypothesis could be formulated and tested, perceived trends could change, and tentative conclusions could be restated.

The material presented here represents our best knowledge regarding what is known about mercury in the Churchill River Diversion, as a result of the activities conducted under this Agreement until April 1, 1984. (In this regard some results of the Agreement projects which were not funded in 1983/84 are also included here). A definitive statement about the results of each project can only be made upon total completion of that project. These results will be presented in each project report which will constitute the technical appendices of the final summary report.

Table 1.1 1983/84 Budget and Expenditures, by Project

Project	Total Agmt. Project Budget	1983/84 Project Budget	1983/84 Expenditures	Expenditures To Date
1.2	100,000	-	-	-
1.3	40,000	-	-	38,069.01
2.1	60,000	20,000	23,000[1]	52,540.27
2.2	42,000	-	-	29,423.62
2.3	40,000	20,000	20,000	32,576.38[2]
2.4	160,000	60,000	60,000	60,000.00
3.1	30,000	-	-	-
3.3	173,000	40,000	41,595.12[3]	79,095.12
4.1	25,000	5,000	-	-
4.2	60,000	20,000	19,822.18	19,822.18
4.3	30,00	-	-	-
TOTAL	760,000	165,000	164,417.30[4]	311,526.58

NOTE:

1. Steering Committee approved an expenditure of $23,000 for Project 2.1, as recorded in minute item 14.3.2.

2. Steering Committee redirected funds from Project 2.2 to Project 2.3 in 1982/83, as recorded in minute item 5.3.5

3. Steering Committee approved an expendutire of $41,595.12 for Project 3.3 as recorded in minute item 14.3.2

4. There was an under expenditure in 1983/84 of $582.70.

CHAPTER 2. PROGRAM 1

2.1 Project 1.1, Mercury in Water and Sediments

This project is one of the three non-funded projects under the Agreement. It was part of an ongoing provincial government program, which was conducted by the Department of Environment and Workplace Safety and Health. However it has been discontinued effective April 1, 1984. This program involved the collection of water samples for analysis of their physical and chemical properties. Bottom sediment samples were also collected and analyzed.

In northern Manitoba, there were twenty-seven sites which were monitored, ten of which were in or near the study area of the Agreement (see Table 2.1). Bottom sediment samples were collected once a year in triplicate. The results of these analysis from 1979 to 1983 are given in Table 2.1. The detection limit for mercury in sediments is 0.02 ug/g (micrograms per gram).

Surface water samples were collected six times a year. The mercury levels in the water were almost always below the detection limit of 0.02 ug/l (micrograms per litre). The occasional result above this level was likely due to a sampling or analytical error.

2.2 Project 1.2 Source and Material Balance

This project is scheduled to begin in 1984/85. The possible direction which should be pursued under this project was discussed at length at the Technical Advisory Committee meeting in November 1983 and again to a lesser extent at their February 1984 meeting. The stated objective of this project is to approximate the distribution and destination of mercury in the northern environment. This investigation would cover possible point sources of mercury, such as gold mines and smelters as well as possible non point sources, such as soil and vegetation.

Table 2.1 Dry weight equivalent total mercury content of lake and river bottom sediments, 1979 to 1983. Results are expressesd as X ± S.D. (ug/g), N = 3.

	LTA.	LONG.	1979	1980	1981	1982	1983
WQ047	56:14	96:05	0.4±0.01	0.04±0.01	<0.03±0.00	<0.04	<0.04±0.00
WQ048	55:13	97:20	-	0.03±0.01	<0.03±0.00	<0.03	<0.04±0.00
WQ049	53:59	97:50	0.03±0.01	0.04±0.01	0.04±0.01	0.06	<0.07±0.01
WQ050	55:46	98:54	0.08±0.00	0.08±0.00	0.05±0.01	<0.03	<0.04±0.01
WQ051	56:46	98:57	0.05±0.01	0.05±0.01	<0.04±0.01	<0.04	<0.04±0.00
WQ093	55:45	97:50	0.02	-	<0.03±0.00	<0.03	<0.03±0.00
WQ385	56:08	100:30	0.02	0.03±0.01	<0.03±0.01	<0.03	<0.04±0.01
WQ389	56:45	99:58	0.07±0.01	0.07±0.02	<0.06±0.02	<0.05	<0.05±0.01
WQ422	55:49	97:42	0.04±0.00	0.04±0.01	<0.03±0.00	<0.04	<0.03±0.00
WQ442	54:37	97:47	0.04±0.00	0.04±0.01	<0.04±0.02	0.06	<0.06±0.03

WQ047 Split Lake near Split Lake Community
WQ048 Sipiwesk Lake near outlet
WQ049 Nelson River at Norway House
WQ050 Footprint Lake near Nelson House Community
WQ051 Southern Indian Lake near South Indian Lake Community
WQ093 Burntwood River near P.R. 391, Thompson
WQ385 Churchill River near Granville Lake
WQ389 Barrington River upstream of Opachuanau Lake
WQ422 Apussigamasi Lake near inlet area
WQ442 Cross Lake near Cross Lake Settlement

Figure 2.1 illustrates the components of the mercury cycle. In order to meet the objective of Project 1.2, the Technical Advisory Committee and the Steering Committee felt that, as a minimum, some relative approximation of the magnitude of each of the components of the mercury cycle must be made. However, the very high cost, or in some cases lack, of existing technology made a rigorous study of a material balance of mercury impossible. In particular, no practical method exists for the measurement of mercury levels in AMBIENT air conditions nor is it possible to determine the amount of deposition of mercury from the atmosphere. The measurement of mercury in the surface water in the study area has consistently shown levels below the existing detection limit. Nor is there any practical method to measure METHYL MERCURY in the water because of its low concentration.

However there are various sources of data which could be amalgamated to provide an indication of what is known about the sources and mercury concentrations in the study area. This data include information on the presence of mercury in the bedrock, the location of existing and closed mines and smelters, possible upstream sources of mercury such as pulp and paper mills, the mercury concentrations in fish from lakes in or near the diversion route, and so forth. The Technical Advisory Committee therefore recommended that, in 1984/85, Project 1.2 should be directed at a compilation of the existing information on the sources and concentrations of mercury in the study area.

2.3 Project 1.3, Mobilization and Methylation

The intent of this project was to try to determine whether the differences in the mercury content in the local fish populations appears to be related to the mercury content of the local flooded soils, more related to the METHYLATION rate of mercury, or are there other overriding conditions in the LIMNOLOGY of the site which effect how much of the mercury gets into the local fish. (Minnows and small fish were used in this survey since they do not integrate conditions over large areas as is the case with larger fish). A corollary to the hypothesis being tested is whether there has been a depletion of the natural mercury found in the local flooded soils since flooding occurred.

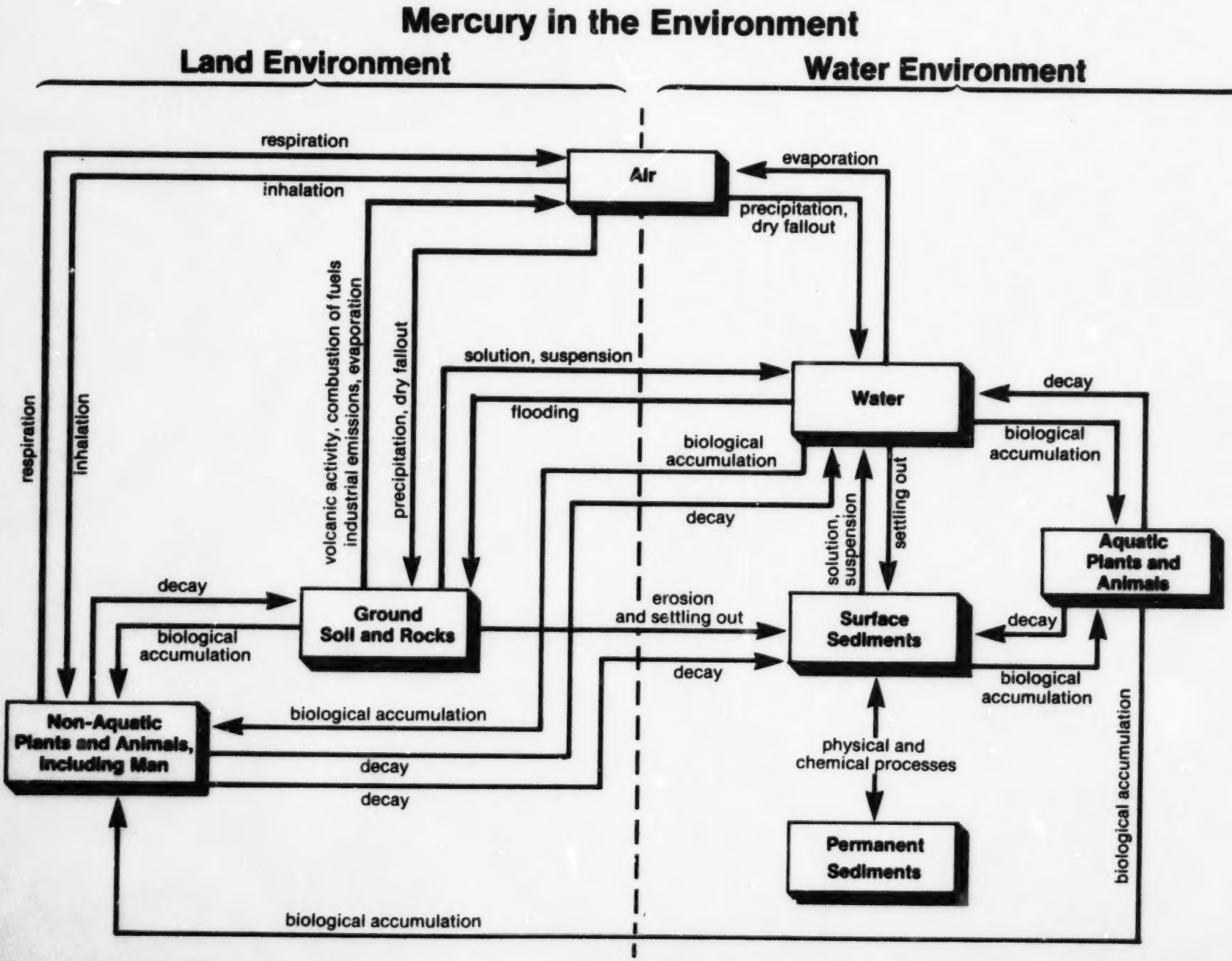

Mercury in the Environment
Land Environment
Water Environment
respiration
inhalation
Air
evaporation
precipitation, dry fallout
volcanic activity, combustion of fuels industrial emissions, evaporation
precipitation, dry fallout
solution, suspension
flooding
Water
decay
biological accumulation
biological accumulation
decay
solution, suspension
settling out
Aquatic Plants and Animals
respiration
inhalation
decay
Ground Soil and Rocks
biological accumulation
erosion and settling out
Surface Sediments
decay
biological accumulation
decay
biological accumulation
Non-Aquatic Plants and Animals, Including Man
decay
decay
physical and chemical processes
Permanent Sediments
biological accumulation
biological accumulation

Figure 2.1

In 1981, the first year of this project, an extensive coverage of sites in and adjacent to the Churchill River Diversion area was undertaken. A total of thirteen sites were selected, eleven flooded sites and two which were unaffected by flooding - Granville Lake and East Mynarski Lake. Measurements were made at these sites of mercury methylation rates, mercury content of the local fish populations, and a number of LIMNOLOGICAL PARAMETERS.

Usually ten to twelve soil cores above the water line and another series from flooded soil below the water line were taken at each site and analyzed for total mercury content. In addition samples were taken with an Ekman dredge from offshore lake bottom sediment which had existed before the lake was flooded. The results showed no major regional differences in the amount of mercury in soils. The range of values measured were approximately .03µg/g (micro grams/gram) to .08 µg/g dry weight. These values were in good agreement with the values measured under Project 1.1. Since there was very little difference in the total mercury content of the soils surrounding flooded lakes, there was no relationship in the total mercury content of flooded soil and the total mercury content of the local fish population.

Other work conducted in 1981 suggested a hint of some depletion of mercury in the soil was occurring in the flooded soils versus the unflooded soils, but the differences were not significant.

Fish mercury levels were found to be distinctly higher at flooded sites, as compared to unflooded sites. (See Tables 2.2 and 2.3) Two limnological parameters showed some correlation with the mercury content of the fish. The mercury content of the fish seems to be correlated with the mercury content in large ZOOPLANKTON. There also seems to be a negative relationship between the percent oxygen saturation of the water and the mercury content of the fish. In other words as the oxygen concentration in the water decreases, the mercury concentration in the fish increases.

Table 2.2 Total mercury content of spottail shiner muscle for samples taken from 10 sites in the area of the Churchill River Diversion, 1982.

Site	n	Total mercury conc. (ug/g)			Total length of fish sample (mm)	
		mean	(range)	(s.d.)	mean	(range)
Area 5, S.I.L.	12	0.15	(0.12-0.20)	(0.02)	70.2	(64-80)
Area 4, S.I.L.	12	0.15	(0.09-0.21)	(0.04)	72.3	(60-79)
Methyl Bay, S.I.L.	12	0.11	(0.05-0.16)	(0.03)	71.2	(66-79)
Long Bay, S.I.L.	5	0.10	(0.09-0.11)	(0.01)	81.2	(67-93)
Area 6 (South Bay), S.I.L.	12	0.10	(0.07-0.15)	(0.02)	72.7	(65-84)
Granville Lake*	12	0.05	(0.03-0.07)	(0.01)	74.2	(68-79)
West Mynarski Lake	12	0.15	(0.11-0.20)	(0.03)	74.6	(66-86)
East Mynarski Lake*	12	0.05	(0.03-0.06)	(0.01)	70.8	(63-79)
Notigi Lake, West Basin	12	0.19	(0.16-0.24)	(0.02)	75.1	(71-80)
Notigi Lake, East Basin	12	0.24	(0.12-0.32)	(0.06)	76.2	(72-81)

* = unflooded sites

Table 2.3. Total mercury content of yellow perch muscle for samples taken from 7 sites in the area of the Churchill River Diversion, 1982.

Site	n	Total mercury conc. (ug/g)			Total length of fish sample (mm)	
		mean	(range)	(s.d.)	mean	(range)
Area 5, S.I.L.	12	0.09	(0.06-0.13)	(0.02)	62.3	(58-70)
Area 4, S.I.L.	7	0.11	(0.08-0.15)	(0.03)	64.3	(62-70)
Methyl Bay, S.I.L.	12	0.06	(0.03-0.11)	(0.02)	62.5	(58-72)
Granville Lake*	12	0.02	(0.01-0.03)	(0.01)	65.7	(64-70)
West Mynarski Lake	12	0.11	(0.06-0.27)	(0.06)	65.5	(57-72)
East Mynarski Lake*	12	0.02	(0.01-0.04)	(0.01)	74.8	(64-81)
Notigi Lake, West Basin	12	0.18	(0.14-0.25)	(0.04)	65.7	(64-70)

* = unflooded sites

In 1981 some measurements of mercury methylation rates were also made. The measurements were made on July 25 and August 18, in sediments in Granville Lake, Issett Lake and South Bay, Southern Indian Lake. Issett Lake had the highest methylation rate. The rates from South Bay, while not much different from those of unflooded Granville Lake, were consistently higher.

In 1982 only seven sites were surveyed. Granville Lake and East Mynarski Lake were again included as controls along with five flooded sites including a new site which was used to define seasonality and patterns of methylation rates in Southern Indian Lake. Again, as in 1981, there were no significant differences in the soil mercury content of the flooded and unflooded sites. In addition there was no depletion of mercury in the flooded soils.

In Methyl Bay, Southern Indian Lake measurements of methylation rates were made over flooded soil and over offshore pre-existing sediments. The two flooded sites had much higher methylation rates than the three offshore sites. There also seemed to be a seasonality to this pattern. The methylation rates were higher in the middle of the summer and lower in late summer. Some preliminary data on DEMETHYLATION rate measurements made in 1983 at this same site in Methyl Bay showed that the demethylation rates were higher over the offshore sediments than over the near shore flooded sediments.

Methylation rates were also measured at Granville and East Mynarski Lakes (control), Southern Indian Lake (marginally flooded) West Mynarski Lake, Issett Lake and Notigi Lake, (the most extensively flooded). The methylation rates increased with the extent of flooding. This order of methylation rates agrees very well with the amount of mercury in the fish collected at these sites in 1982.

The source of mercury has increased in lakes that were flooded. The average concentration of total mercury in the lake bottoms before flooding (offshore areas) was approximately .03 - .05 µg/g dry weight. The average mercury content of the soils that were subsequently flooded is about three times that of the pre-existing lake bottoms. The amount of increase of the mercury in the lake varies with the extent of flooding. The more extensive the flooding, the larger the area of newly flooded soils and hence the greater the relative increase in the amount of mercury. Notigi is an excellent example of this occurrence.

However, depletion of this soil mercury was not demonstrated. The amount of such a depletion would only need to be relatively small in order to account for the increased mercury levels being found in the fish.

Perhaps the most important finding from this project is that it is the total effect of flooded ORGANIC material added to the lake, whether by flooded soil or by erosion, and most especially its effect on increased methylation rates, which has caused the problem of increased mercury levels in fish.

CHAPTER 3. PROGRAM 2

3.1 Project 2.1 Experimental Ecosystems

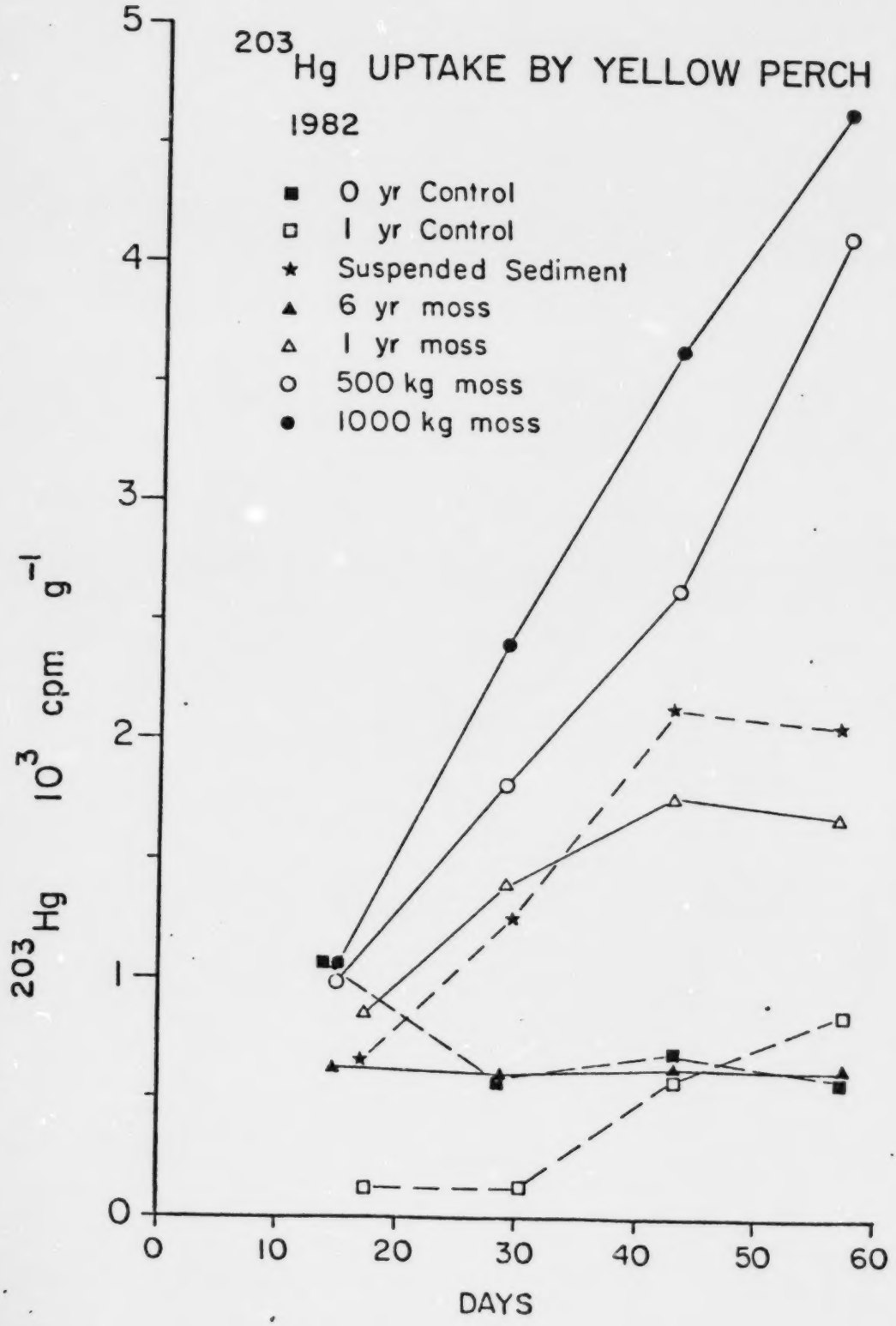
This project is intended to study the effects of changes in the aquatic environment associated with lake impoundment on the BIOACCUMULATION of mercury. The method being used involves the establishment and maintenance of large experimental enclosures (or LIMNOCORRALS) in Southern Indian Lake, each of which are approximately 75 square meters in area and 3 meters deep. The use of this method enables the local food chain to be kept intact and yet allows changes to be made to the experimental ecosystems which simulate impoundment.

Once established the enclosures are then fished out and a known number of yellow perch are added to each one. A precise measure of the volume of each enclosure is calculated. To each of the enclosures a RADIOACTIVE ISOTOPE of mercury is added as mercuric chloride. This ION (Hg^{2+}) can be METHYLATED by bacteria and thus enter into the food chain.

Each enclosure is treated in a specific way. Some are left open to the bottom sediment, some have plastic bottoms. Some are treated to simulate impoundment by the addition of moss, eroding bank clay, or NUTRIENTS. Some are used as controls. A fixed number of perch are then removed from the enclosures for mercury analysis at regular intervals throughout the experiment and the remaining perch are fished out and analysed for mercury upon completion of the experiment.

The 1981 results showed that moss and peat are very important stimulants to bioaccumulation of mercury, as measured by the mercury uptake per gram of muscle tissue in yellow perch. The 1982 results showed that the effect of moss on the stimulation of bioaccumulation of the radioactive isotope of mercury reduces over time. The 1982 results also showed that the addition of suspended sediments from eroding banks enhanced bioaccumulation of mercury. (See Figure 3.1)

FIGURE 3.1


203Hg UPTAKE BY YELLOW PERCH
1982
0 yr Control
1 yr Control
Suspended Sediment
6 yr moss
1 yr moss
500 kg moss
1000 kg moss
203Hg 10^3 cpm g^-1
DAYS
0
1
2
3
4
5
0
10
20
30
40
50
60

In 1983 two of the treatments consisted of replicating the moss treatment. There had never been replicated treatments and the objective was to see how much variation occurred within one year. The results showed that they replicated well. Another treatment consisted of stirring the surface of the lake bottom that had been flooded six years ago, and which had been giving no different response in the 1982 experiments from the controls used. After it was stirred it now had the ability to stimulate the bioaccumulation of mercury. In another treatment when sediment was added along with new moss, there seemed to be a SYNERGESTIC effect with respect to the bioaccumulation of radioactive mercury.

On the basis of the results of these experiments, some tentative conclusions can be made as follows:

1. Lake sediment in Southern Indian Lake is necessary to stimulate bioaccumulation. This is based on those experiments which showed that moss treatments had the strongest effect in those limnocorrals which were over natural lake bottom. Limnocorrals with plastic bottoms did not show significant bioaccumulation.

2. Newly added moss-peat consistently stimulates the bioaccumulation of mercury in fish. (This moss and peat material is the predominant forest floor cover in this region and is estimated to represent one-third of the total terrestrial organic material added to the reservoir by impoundment). The highest rates of bioaccumulation of radioactive mercury occurred under these conditions, but it loses its effect over time.

3. Newly added bank clay also stimulates the bioaccumulation of radioactive mercury, but to a lesser degree than newly added moss-peat. However, this is important in Southern Indian Lake where erosion, the major physical effect of impoundment, is a significant factor.

4. The effects on bioaccumulation of radioactive mercury of newly added moss-peat and of newly added bank clay both decrease with time.

3.2 Project 2.2 Bio-Accumulation Processes

The purpose of this project is to study the mechanisms of mercury transfer between the bottom sediment reservoir and the fish population.

Two sets of samples were collected in 1981: one set in late June for mercury and trace metal analysis, and the other set in mid-August for TAXONOMIC purposes.

Basic ignition analysis and particle size analysis were done. The ignition analysis showed that the mineral content of the sediment was highest in South Bay, Southern Indian Lake, followed closely by Long Bay, Southern Indian Lake, and Rat Lake, with Mynarski Lake being the lowest. The converse of mineral content is organic content which is a crude measurement of food available to the BENTHIC communities. The particle size analysis showed that the particle size was finer in Long Bay than in South Bay, and that they were very evenly distributed in Rat and Mynarski Lakes.

The number of CHRONOMIDS per square meter was determined at the sampling sites, as was the relative size of the individuals sampled at the different sites. Determination of the number of SPECIES of chronomids located at each sample site as well as an estimate of the distribution of individuals among the different species type was undertaken. Any apparent deformities in the bodies of the sampled chronomids were also noted. On the basis of these combined pieces of information, tentative conclusions have been made concerning whether the chronomid populations sampled were experiencing stress.

There was some indication of stress in the chronomid populations of Long Bay and South Bay which are both part of Southern Indian Lake. The Rat and Notigi Lakes system did not seem to be balanced in terms of stress. Only in Mynarski Lake did there not seem to be any problem with stress in the chronomid population.

Calculations of the amount of mercury in three different levels of the benthic food chain were made. For each level, the amount of mercury in the individuals increased by one order of magnitude. The relationship seemed to hold whether in the high end of the spectrum (Long Bay or South Bay) or in the low end (Notigi Lake). A calculation was also made of the total amount of mercury that would be available through the benthic community if the fish were to eat all the benthic fauna available. The amount of mercury held in the benthic community was by far the largest in Mynarski Lake, then decreasing to Rat Lake, and then to approximately the same levels in Long Bay and South Bay.

3.3 Project 2.3 Biogeochemistry of Sediments

The objective of the project is to investigate the relationships between the environmental effects of impoundment and the forms, abundance and bio-accumulation of mercury. The formation and breakdown of methyl mercury are particularly important because this form of mercury is highly toxic and is readily incorporated into the food chain. Methyl mercury is produced (from INORGANIC BIVALENT mercury) and is decomposed (demethylated) by a number of different microbes under a wide range of environmental conditions. Changes to the environment, such as those caused by impoundment of rivers can change the number and type of microbes and hence alter the rates of mercury methylation, demethylation, and bioaccumulation.

In 1981, Dr. Jackson, in cooperation with Dr. Warwick, undertook a study of mercury in sediments, water and biological samples from eight sites in Notigi Reservoir, Southern Indian Lake, and Granville Lake (a control region). The results of this work are currently being evaluated and prepared for publication. These results suggest that (1) methyl mercury production per unit amount of inorganic mercury in the reservoirs is greatest where flooding of adjacent land has been greatest, and that (2) the inferred stimulation of methylation by flooding is due to stimulation of microbial activity caused by incorporation of terrestrial organic matter into the aquatic ecosystem. Suprisingly, mercury levels in benthic INVERBRATES were highest where sediment mercury levels were relatively low. This result is consistent with the working hypothesis that the concentrations of certain METAL BINDING MINERAL COLLOIDS in the sediments have an important bearing on the bioaccumulation of mercury by these animals.

In 1983, Dr. Jackson initiated a new two-year research effort to confirm and expand the previous work, with emphasis, this time, on controlled laboratory experiments for investigating the effects of environmental variables on the methylation and demethylation of mercury by sedimentary microbes. (Both processes must be examined, because both contribute to the observed result: the rate of methylation in a natural environment is a <u>net</u> rate representing a balance between methylation and demethylation). Sediment and water samples

were taken from twelve field sites, including the eight sites sampled in 1981. In the experiments, sediment-water mixtures are incubated under different defined environmental conditions in the presence of added inorganic bivalent mercury for the study of methylation or in the presence of added methyl mercury for the study of demethylation. Certain measurements are then made.

The results have confirmed the tentative conclusions based on the 1981 study, indicating that flooding of land increases the net rate of microbial methyl mercury production by introducing organic nutrients (especially decomposing plant debris) into the aquatic environment, thereby stimulating the growth of certain methylating microbes. In the experiments, the environmental conditions have been altered by varying the REDOX conditions and pH, by adding different organic substrates, and by adding shoreline material. The work is continuing and the effects of additional environmental factors, such as clay sized minerals, will be tested.

In brief, the observations made thus far include the following: (1) Rates of microbial mercury methylation and general microbial activity, as well as methyl mercury concentrations in water and sediments and mercury levels in fish, are increased as a result of environmental changes caused by impoundment, are greatest where the areal extent of flooding has been greatest (thus, are higher in Notigi Reservoir than in Southern Indian Lake), and are much higher in regions of recently flooded soil and terrestrial vegetation than in offshore areas. (Total mercury concentrations in sediments are also slightly elevated in regions affected by impoundment, implying increased levels of inorganic bivalent mercury, but this alone cannot account for the observed enhancement of methylation). (2) The observed enhancement of mercury methylation and bio-accumulation has resulted from stimulation of the activities of micro-organisms - especially anaerobic bacteria - by the introduction of decomposing organic matter from flooded land. Experimental data showed enhanced rates of methylation with an increase in organic nutrients. Methylation rates were higher under anaerobic conditions than under aerobic conditions, although methylation was suppressed by highly REDUCING conditions. But methylation occurred under both aerobic and anerobic

conditons, and presumably involved activities of several different kinds of microbe (including methane bacteria, which may play an important role in mercury methylation in anaerobic environments where organic nutrients are abundant (for instance, on flooded land)). Demethylation of mercury was also observed under both aerobic and anaerobic conditions, but the overall effect of nutrient enrichment, especially in the absence of oxygen, was stimulation of methyl mercury production. (3) Both methylation and demethylation are favoured by neutral pH conditions. This indicates that the supposed preference of methylating bacteria for moderately acidic conditions which has been noted by other workers in the literature is not universal.

The observations obtained thus far are in good agreement with results reported by scientists working on other projects under the Agreement, especially Projects 2.1 and 2.4

3.4 Project 2.4 Limnological Survey

The objective of this project is to determine if the aquatic ecology of the impounded areas has achieved a new steady state or if the affected areas are still in rapid transition. The Department of Fisheries and Oceans had monitored a number of parameters at sites in Southern Indian Lake and Notigi from 1974 to 1978. By studying these same parameters at the same locations now, Dr. Hecky hopes to be able to determine if the ECOSYSTEMS are different now from those which existed immediately following impoundment when methyl mercury problems apparently first arose.

Results from their other projects suggest that impacts of organic material and eroded bank material have stimulated bioaccumulation of mercury in the systems. Addition of these materials have a defined, measurable effect on the aquatic ecosystems. If the additions are declining over time then it might be possible to forecast the future states of Southern Indian Lake and Notigi, and in this manner obtain an indirect way of determining a long term forecast of the mercury problem. The return time for mercury problems in impoundments is something which has not been documented in the literature.

The previous monitoring showed that there were some important differences in the nature of the flooding at Southern Indian Lake (S.I.L.) and Notigi. In S.I.L. there was only marginal flooding whereas Notigi experienced extensive flooding, with greatly increased terrestrial areas now under water. Another important difference was that at S.I.L, a major effect of flooding was greatly increased TURBIDITY, whereas at Notigi, a major effect was high rates of oxygen demand.

Southern Indian Lake experienced a large increase in suspended sediment - primarily as a result of eroded shorelines. Prior to impoundment, the Churchill River was the primary source of sedimentary material and approximately 50% of river-derived suspended material was retained within S.I.L. After impoundment eroding shorelines increased sedimentary input by a factor of 20. While a larger amount of sediments is leaving Southern Indian Lake, in suspension, than before impoundment, approximately 80-90% of the newly eroded material is being deposited in S.I.L. There has been greatly reduced light penetration in S.I.L. These processes are still ongoing in S.I.L. with sediments and terrestrial material still being introduced.

Notigi impoundment began in the winter of 1974. There followed a period of very high and variable chlorophyll concentrations - as algae blooms. A high rate of oxygen demand was also noted up to 1976. In 1977, with the release of water down the diversion channel there was a substantial improvement in water quality. The limnological survey work under Project 2.4 is re-estabishing the data base to see if there has been a continued improvement. The improvement in 1977 and 1978 could indicate that input of organic material was declining, however the improvement may only be due to higher flushing by the diversion. The 1983 summer data indicate that while the oxygen concentrations at all depths have improved, there are still areas of high oxygen demand within Notigi Reservoir. (See Figure 3.2)

Continuation of the limnological survey will provide a data base through time to see how the system is changing. In particular, looking at parameters like oxygen and sediment concentrations will provide an indication of whether the system is evolving away from the post impoundment stage. If not, then this might mean that a long term quasi-steady state might persist for some time, indicating that the mercury problem will continue.

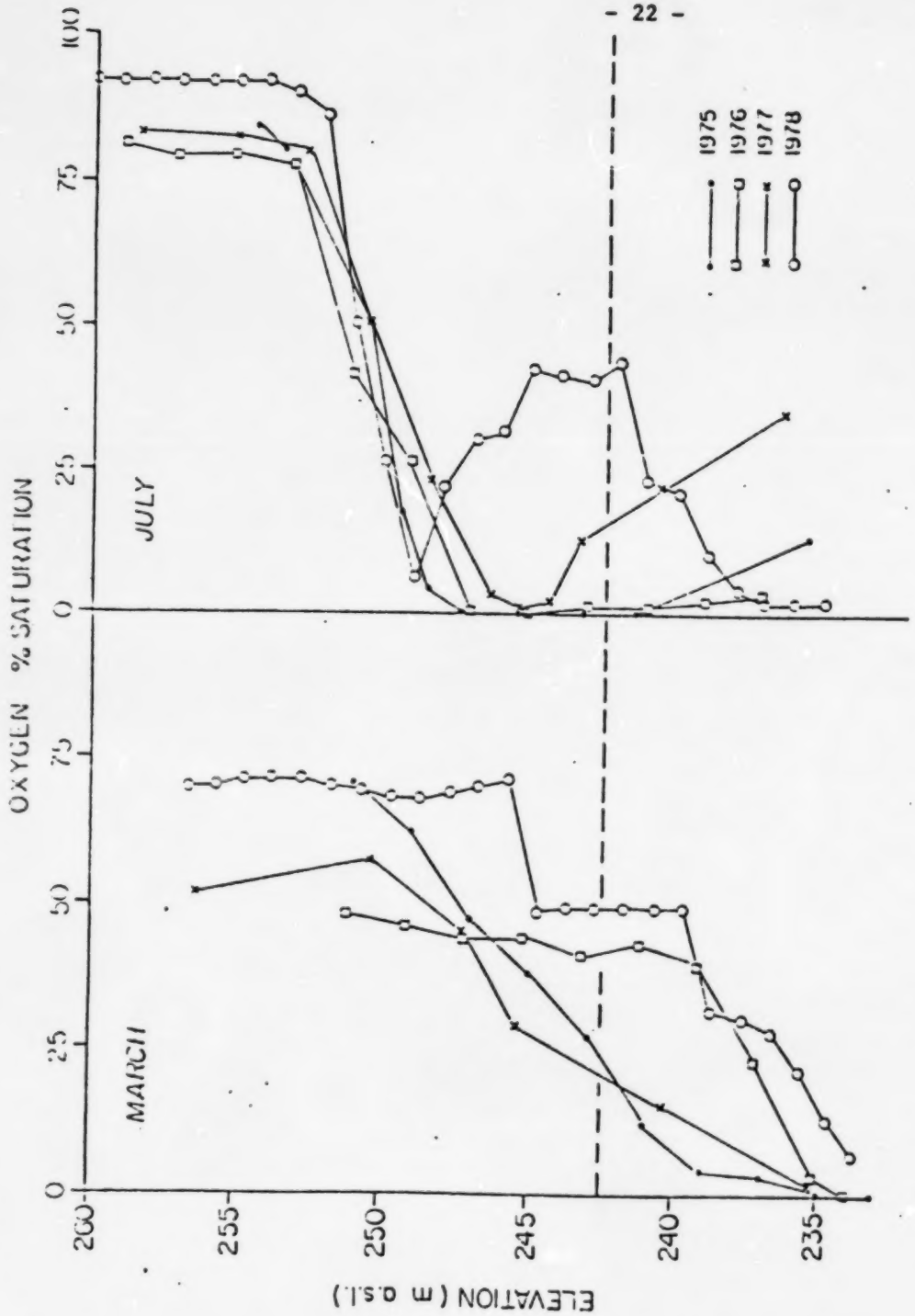


FIGURE 3.2 WINTER AND SUMMER OXYGEN PROFILES FOR THE EASTERN BASIN OF NOTIGI LAKE, 1975-1978

Source: Bodaly, R.A., D.M. Rosenberg, M.N. Gaboury, R. E. Hecky, R.W. Newbury, and K. Patalas. "Ecological Effects of Hydroelectric Development in Northern Manitoba, Canada: The Churchill-Nelson River Diversion." *In Effects of Pollutants at the Ecosystem Level*, edited by P.J. Sheehan, D.R. Miller, G. C. Butler and Ph. Bourdeau.
SCOPE: John Wiley and Sons Ltd., 1984.

CHAPTER 4. PROGRAM 3

4.1 Project 3.1, Mercury in Fauna

This project will not receive funding under the Agreement until 1984/85. However, Dr. E Kucera, the project leader conducted a pilot study of the mercury levels in mink and otter in 1980 in Manitoba. Some of the results of that study are presented here to provide a background on the work carried out to date and an indication of the work planned in the Diversion area.

There are three reasons for monitoring mercury levels in fauna; because of their importance as a potential food source, a revenue source, and as biological indicators of mercury levels in the environment. While mink and otter are seldom used as a food source, other food sources may have the potential for elevated mercury levels (eg. waterfowl meat and eggs).

The mink and otter trapped along the Burntwood River area provide the trappers with an income of approximately $500,000. This source of income could be affected by elevated mercury levels in two ways. Excessive intakes of mercury may lead to reproductive failures and lower numbers of animals. Secondly, sufficiently high levels of mercury in these animals (approximately 7 ppm in the brain) will cause poisoning.

Predators, such as mink and otter, are among the best indicators of mercury in the environment. Their position near the top of the food chain results in greater bioaccumulation of mercury in their bodies than in those animals located in the lower trophic levels. The results of Dr. Kucera's pilot study showed that these animals accumulate about ten times as much mercury in their tissues as did the fish in the same rivers. (see Table 4.1)

Five areas of Manitoba were surveyed in this pilot study: Duck-Porcupine Mountains, Burntwood River, Grass River, Winnipeg River, and Whiteshell River. (see Figure 4.1) The highest mercury levels were found in the mink and otter taken from along the Winnipeg River, followed by those taken along the Burntwood River (see Table 4.1). The mercury levels of those animals taken from the other three sites were the same as those levels quoted in the literature as normal.

Table 4.1 Mercury levels in Manitoba mink (micrograms per gram of freeze-dried tissue, *mean ± SD (range))

Area	Males				Females			
	n	Liver	Kidney	Brain	n	Liver	Kidney	Brain
Duck Mountain	22	1.05±1.29 (0.13-6.32)	1.02±1.25 (0.06-5.56)	0.36±0.23 (0.11-1.14)	21	3.44+2.38 (0.09-7.79)	2.32±1.61 (0.08-5.40)	0.93±0.55 (0.05-1.97)
Wekusko	10	2.35±1.74 (0.49-5.12)	2.33±1.55 (0.53-4.81)	0.75±0.89 (0.80-3.13)	9	4.68±3.80 (0.05-10.13)	2.31±2.61 (0.10-8.17)	1.78 ±0.95 (0.44-2.66)
Whiteshell	18	3.38±2.10 (1.22-7.50)	3.18±2.03 0.82-8.63)	1.05±0.60 (0.44-2.92)	9	4.87±2.51 (0.65-8.03)	3.44±2.10 (0.45-5.55)	1.51±0.78 (0.35-2.80)
Burntwood	15	4.13±2.65 (1.03-10.51)	2.40±1.71 (0.46-7.46)	1.23±0.81 (0.49-3.14)	6	7.31±8.17 (3.07-23.86)	7.02±8.68 (2.03-23.5)	5.28 ±8.19 (0.69-19.69)
Winnipeg River	33	7.45±5.19 (1.25-24.29)	6.08±4.05 (1.01-14.83)	2.66±1.95 (0.29-7.41)	29	12.31±6.23 (0.43-25.99)	8.05±4.35 (0.43-18.8)	3.36±1.59 (0.17-6.29)

Source: Kucera, E. 1983. Mink and Otter as Indicators of Mercury in Manitoba Waters. Can. J. Zool. 61: 2250-2256.

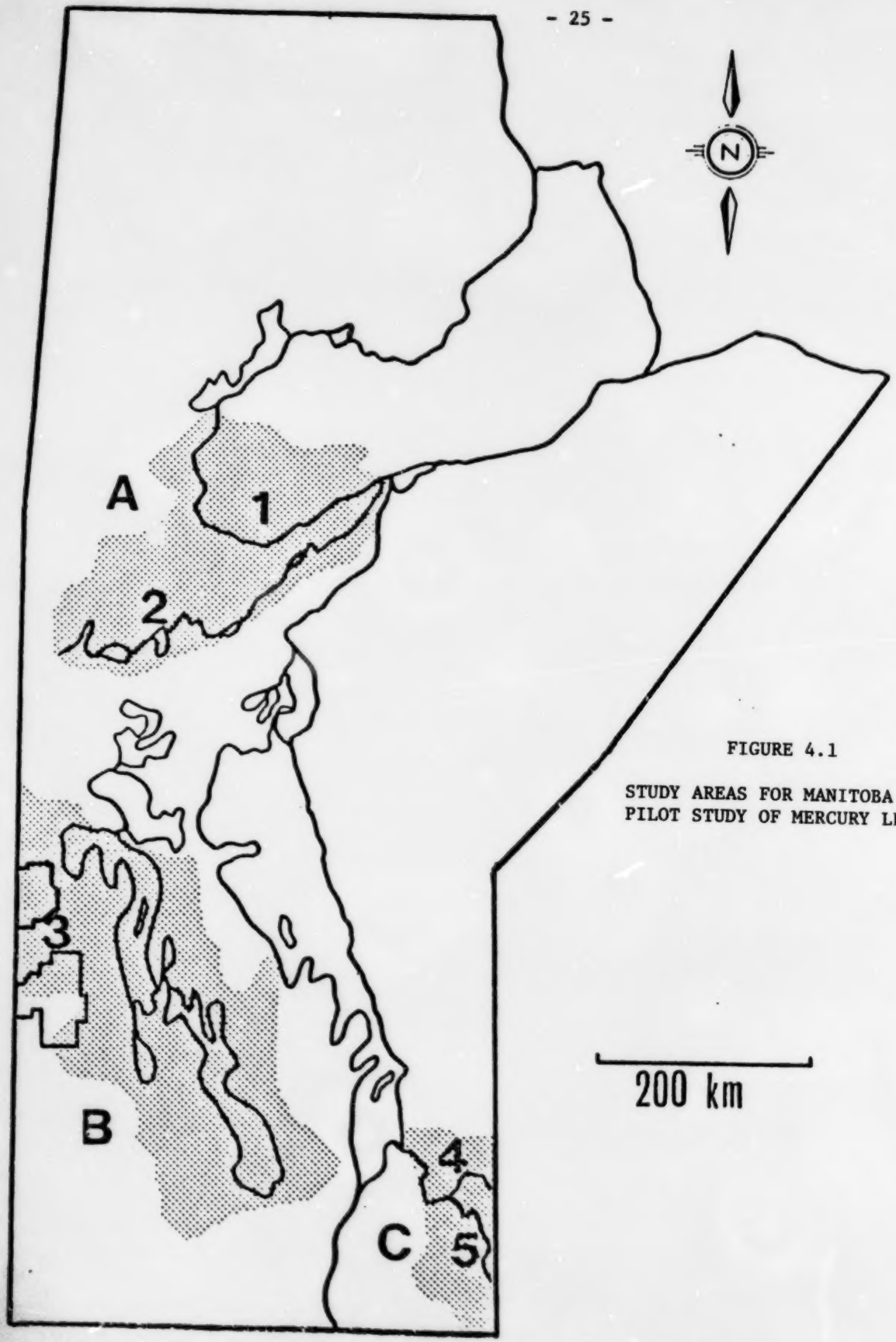


FIGURE 4.1

STUDY AREAS FOR MANITOBA MINK
PILOT STUDY OF MERCURY LEVELS

Another important aspect of monitoring mercury levels in mink is the similarity of their physiological response to mercury to that of humans (see Figure 4.2).

When Project 3.1 begins in 1984/85, mink carcasses will be collected from trappers along the Burntwood River and analyzed for mercury. Small mammals, such as mice, will be trapped in the summer to provide some indication regarding the presence of increased mercury levels in the terrestrial food chain.

4.2 Project 3.2 Commercial Fish Surveys

This project is not cost shared under the Agreement. It is part of the legislative mandate of the Department of Fisheries and Oceans which includes, among other things, monitoring the mercury levels of commercial fish catches. The tolerance level for mercury in commercial fish set by the Canadian Government for the sale of fish in Canada is 0.5 ppm. In the United States the limit is set at 1.0 ppm. (Those commercially harvested fish which contain a mercury level between 0.5 ppm and 1.0 ppm may therefore be exported for sale in the United States, but can not be sold in Canada).

The emphasis in the Department of Fisheries and Oceans (D.F.O.) mercury program since 1975 has been to monitor those lakes which have been identified as problem lakes. However, the commercial fish from most of the lakes that are in or near the Agreement area could still be marketed in the United States during 1983/84. Table 4.2 shows the results of the mercury analysis of these lakes for 1983/84.

D.F.O.'s monitoring program generates a large quantity of data. This data is computerized and analyses can be generated of any of the recorded parameters including trends over time. However, until 1983 most of the data was clustered in a few consecturive years. Trend analyses for only two or three years would be very suspect and difficult to justify statistically.

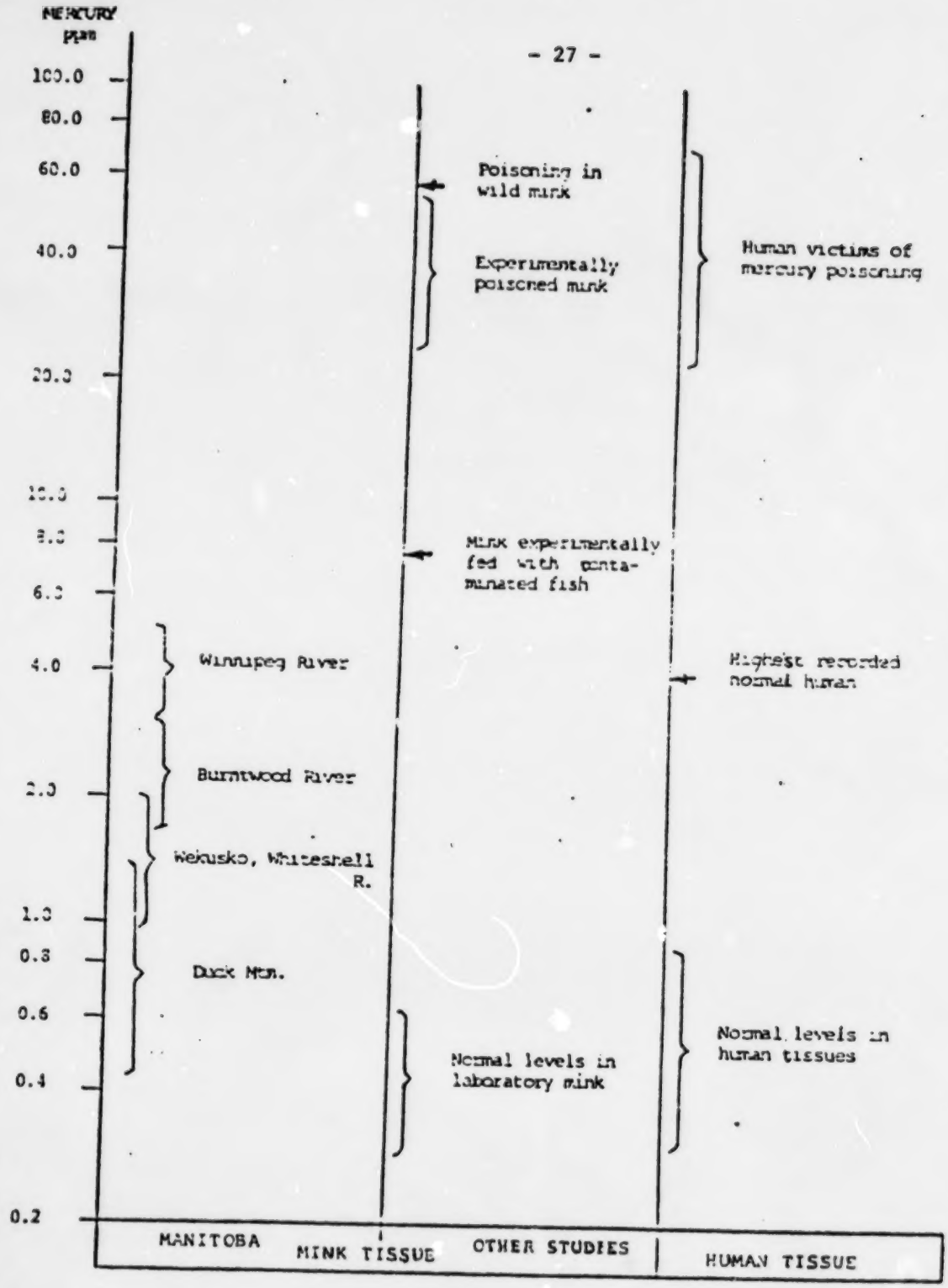


Figure 4.2 Average levels of mercury in liver tissue

Table 4.2 Mercury Levels for Northern Pike and Pickerel for Selected Lakes, 1983.

LAKE	SPECIES	NO.SAMPLES	MEAN PPM	RANGE PPM
Leftrook	Pickerel	1	0.18	
Mynarski	N. pike	4	0.45	0.33-0.57
	Pickerel	4	0.54	0.36-0.71
Nelson R.	N. pike	6	0.90	0.52-1.25
	Pickerel	1	0.51	
N. Indian	N. pike	1	0.41	
Osik	N. pike	1	1.83	
	Pickerel	3	0.57	0.09-1.05
Sipiwesk	N. pike	15	0.95	0.43-1.90
S. Indian	N. pike	26	0.81	0.32-1.27
	Pickerel	3	0.49	0.26-0.61
Wuskwatim	Pickerel	3	0.81	0.79-0.84

In addition to concentrating primarily on the problem lakes, sampling is also focused on northern pike, pickerel, and lake trout, since these are the main commercial species which may have mercury problems.

Commercial sampling results are based on the mean values of pooled samples, that is, one fillet from a few fish from each shipment are combined together for analysis. However D.F.O. also measures and analyses the individual fish before they are pooled for all samples from lakes in the Agreement study area.

4.3 Project 3.3 Fish Surveys and Fish Eating Guide

In 1983/84, Project 3.3 was directed by two project leaders, Dr. D. Bodaly and Dr. J. O'Connor. Each portion will be discussed separately here.

Dr. Bodaly's project involved sampling fish for their mercury content at a number of sites in Southern Indian Lake and at the top end of Notigi Reservoir (formerly Issett Lake). (See Table 4.3) In 1983/84, four sets were fully sampled - three in Southern Indian Lake and one in Issett Lake, with some information obtained from an additional three sites. In 1982/83, the first year of funding under the Agreement, six sites were sampled - five in Southern Indian Lake and one in Issett lake.

A mimimum of twenty-four fish of each species were analyzed from each site. The selected species were those which are domestically harvested, such as whitefish, northern pike, and walleye. In addition to their mercury content, other characteristics of each fish were also recorded, such as weight and age.

Fish samples were first collected by Dr. Bodaly for mercury analysis in 1978 or 1979 depending on the particular site. The only pre-impoundment fish analysis undertaken by Dr. Bodaly were of whitefish samples which were caught in 1975, frozen, and analyzed in 1978.

Table 4.3 - 1983 Mercury Concentrations from D.F.O.'s Fish Survey Program
(Mercury concentrations in micrograms/gram wet weight, sample size in parentheses)

	Whitefish	Cisco	Pike	Walleye	Longnose Sucker	Burbot
SIL - Camp 9	0.09 (26)	0.15 (24)	0.68 (25)	0.47 (21)	0.08 (25)	0.18 (5)
SIL - Channel	0.15 (34)	0.17 (27)	0.65 (36)	0.50 (25)	0.07 (16)	-
SIL - South Bay	0.15 (28)	0.24 (36)	0.83 (23)	0.56 (36)	-	-
SIL - Area 4	0.05 (24)	-	-	-	-	-
Issett Lake	0.17 (24)	0.25 (24)	1.04 (35)	1.37 (33)	-	-
Notigi Lake	-	-	1.76 (19)	-	-	-
Missi Falls	-	-	-	-	0.16 (24)	-

Analysis of mercury content of the whitefish showed a marked increase in 1978 when compared with the mercury level in whitefish caught in 1975. All sites monitored have shown a consistent decrease in the average mercury content of the whitefish since 1978 or 1979. For most sites, mercury levels were still significantly above pre-impoundment levels, but they were noticeably lower than the highest recorded levels in this species. (The highest levels perhaps occurred between 1975 and 1978, a time period when Dr. Bodaly was not undertaking fish surveys). The decreasing mercury levels of the whitefish are not indicative of other species. Whitefish mercury levels are generally lower than other species because whitefish are near the bottom of the food chain and they tend to be located more in the middle of the lake, where methyl mercury levels in the sediments are lower than those near the flooded shorelines.

The post impoundment trend from 1978/79 to 1982 in the northern pike being surveyed by Dr. Bodaly was one of generally stable or perhaps slightly increasing mercury levels. Northern pike are a predatory fish and are most associated with the flooded areas of the new reservoirs. It is logical to expect it to be the one to show the highest increases and for the longest period of time.

Another predatory fish being sampled by Dr. Bodaly is walleye (pickerel). Again the commercial fish samples were the only pre-impoundment value for this species. Both Dr. Bodaly's samples and the commercial fish samples showed major increases in the mercury levels of walleye after impoundment, however, there was a large variation from year to year.

The same mesh of GILL NET is used to collect the survey samples each year. Many of the fish being sampled represent a wide range of ages. However, because the HALFLIFE of mercury in fish is two hundred days, the fish sampled each year are reflecting trends from year to year.

In summary Dr. Bodaly's results show that the mercury levels of the whitefish sampled in Southern Indian Lake and Issett Lake are declining but still are above pre-impoundment levels. The mercury levels in the predatory fish such as northern pike and walleye have not decreased five years after the impoundment. These results are consistent with the commercial fish sampling

results for these species in these locations. Examination of the commercial fish sampling results for other nearby lakes which were not flooded does not show any increasing mercury levels for these lakes.

Dr. J. O'Connor's objective under Project 3.3 is to determine the mercury levels of fish from selected areas along the diversion route. However, as a result of his departmental responsibilities he also has broader management objectives as well, such as the allocation of the fish populations among commercial, domestic and sport fishermen. In the fulfillment of these objectives he received assistance not only from the Canada-Manitoba Mercury Agreement but from other programs such as the Resource Management Assistance Program (RMAP) and the Natural Resource Officer Trainee Program (NRONP), as well as assistance from Natural Resources Conservation Officers and Local Guides.

There were some minor differences in the methods used by Dr. Bodaly and Dr. O'Connor to obtain their samples. These differences include the use of different gill nets and different sampling sizes (50 samples versus 25). However, both groups had their fish samples analyzed for mercury in the same Department of Fisheries and Oceans laboratory used to analyze the commercial fish samples for mercury.

In 1983/84 Dr. O'Connor sampled fish from seven sites along the diversion route - Wapisu, Rat, Threepoint, Notigi - East and West, Footprint, Mystery and Split Lake. Five of these lakes are fished domestically. Two other lakes outside the main diversion route were also sampled - Sipiwesk and Stephens. (See Table 4.4)

A total of 7900 fish were caught. Of these 1899 were analyzed for mercury content. Walleye, northern pike, whitefish and sauger (the higher value fish) made up 61.7% of the 1899 fish analyzed for mercury. In addition, fish characteristics such as weight, length and sex were also recorded.

Table 4.4 1983 Mercury Concentrations from D.N.R.'s Fish Survey Program

Lake Name	Species	No. Fish	Mean (ppm)	Range (ppm)	Mean Kg
Rat	Whitefish	23	0.29	0.13-0.70	1.35
	N. pike	22	1.54	0.30-2.45	1.71
	Pickerel	50	1.79	0.34-4.10	0.82
	Tullibee	18	0.38	0.21-0.77	0.41
	Sauger	1	2.85		0.55
	TOTAL:	114			
Wapisu	Whitefish	41	0.31	0.09-0.82	0.78
	N. pike	53	1.97	0.57-3.42	2.30
	Pickerel	50	1.05	0.33-2.46	0.34
	Tullibee	25	0.39	0.21-0.69	0.38
	Sauger	37	1.85	0.37-2.84	0.20
	Yellow perch	3	0.40	0.31-0.54	0.19
	L.N. Sucker	3	0.60	0.57-0.62	1.57
	TOTAL:	212			
Notigi	Whitefish	48	0.20	0.06-0.48	0.82
	N. pike	21	1.19	0.15-2.01	1.42
	N. pike(NB)	24	1.13	0.29-2.23	1.31
	Pickerel	11	1.62	0.61-2.37	0.77
	Pickerel (NB)	16	1.20	0.40-2.95	0.69
	Tullibee	25	0.30	0.10-0.67	0.48
	White Sucker	8	0.33	0.08-0.57	1.20
	TOTAL:	153			
Mystery	Whitefish	21	0.19	0.05-0.45	0.59
	N. pike	50	1.06	0.51-2.05	1.80
	Pickerel	21	0.82	0.13-1.59	0.96
	Tullibee	25	0.25	0.13-0.57	0.43
	Yellow perch	18	0.39	0.18-0.79	0.20
	Mooneye	19	0.25	0.15-0.51	0.23
	TOTAL:	154			
Stephens	Whitefish	20	0.24	0.07-0.45	1.42
	N. pike	45	1.41	0.37-3.66	1.84
	Pickerel	9	1.78	0.97-2.60	1.46
	Tullibee	26	0.17	0.08-0.43	0.20
	Sauger	25	0.69	0.17-1.36	0.31
	L.N. Sucker	12	0.20	0.05-0.36	0.69
	Mooneye	25	0.15	0.09-0.29	0.16
	White Sucker	6	0.10	0.06-0.17	0.56
	TOTAL:	168			

Lake Name	Species	No. Fish	Mean (ppm)	Range (ppm)	Mean Kg
Threepoint	Whitefish	25	0.24	0.10-0.56	0.85
	N. pike	50	1.58	0.25-3.53	1.15
	Pickerel	50	1.36	0.32-2.70	0.53
	Tullibee	22	0.31	0.16-0.64	0.35
	Sauger	43	1.61	0.40-2.85	0.22
	Yellow perch	6	0.43	0.31-0.58	0.18
	R.N. Sucker	3	0.48	0.38-0.65	0.87
	L.N. Sucker	25	0.52	0.13-0.91	1.18
	White sucker	19	0.44	0.17-0.91	0.92
	TOTAL:	243			
Footprint	Whitefish	25	0.18	0.06-0.48	0.87
	N. pike	41	1.20	0.45-2.40	0.86
	Pickerel	33	1.13	0.36-1.85	0.47
	Tullibee	24	0.35	0.13-0.57	0.38
	Sauger	25	1.69	0.46-2.41	0.31
	Maria	21	0.35	0.17-0.85	0.94
	White Sucker	18	0.35	0.09-0.60	0.84
	TOTAL:	187			
Sipiwesk	Whitefish (001)	16	0.05	0.01-0.12	1.22
	N. pike (001)	43	0.55	0.07-1.60	1.40
	Pickerel (001)	56	0.63	0.07-1.21	0.48
	Tullibee (001)	26	0.06	0.02-0.16	0.39
	Sauger (001)	33	0.41	0.11-0.82	0.22
	Goldeye (001)	25	0.13	0.07-0.35	0.27
	Y. Perch (001)	3	0.14	0.09-0.23	0.17
	Sheepshead (001)	6	0.16	0.07-0.25	1.17
	R.H. Sucker (001)	22	0.19	0.02-0.68	0.69
	White Sucker (001)	25	0.12	0.02-0.72	0.95
	TOTAL	255			
Split	Whitefish (001)	27	0.08	0.03-0.21	0.69
	N. pike	53	0.45	0.10-1.19	1.41
	Pikcerel	64	0.53	0.08-1.02	0.64
	Tullibee	17	0.09	0.01-0.38	0.27
	Sauger	48	0.65	0.24-1.23	0.25
	Goldeye	1	0.21		0.30
	Y. Perch	2	0.37	0.26-0.47	0.25
	Maira	15	0.11	0.03-0.31	0.47
	Sheepshead	4	0.21	0.15-0.25	1.15
	L.N. Sucker	13	0.29	0.05-0.50	0.98
	Mooneye	25	0.11	0.05-0.20	0.22
	White Sucker	29	0.21	0.02-0.43	1.14
	TOTAL:	298			

Some of the lakes sampled by Dr. O'Connor have been sampled previously for mercury analysis. However, the number of previous years of data varies from one site to another and the data that is available is not necessarily for continuous years.

The large number of fish collected for mercury analysis, representing a large number of different size and age groups might enable an improvement to be made in the CORRELATION COEFFICIENT for the REGRESSION ANALYSIS of mercury and fish size. If this analysis shows that smaller sized fish have lower mercury concentrations, then serious consideration will be given to allowing smaller sized fish to be legally caught for domestic consumption.

In 1984/85 Dr. O'Connor hopes to expand his work on mercury in fish by conducting domestic surveys to obtain such information as the individual's level of fish consumption, where his fish are caught, and the size and species of the fish he is eating.

4.4 Project 3.4, Mercury in Hair of Native People

The Federal Department of Health and Welfare was involved in 1983/84 in taking hair and blood samples for mercury analysis from the native people living in the communities along the diversion route. This ongoing program is not cost shared under the Agreement. However liaison with this department is maintained through their representation on the Technical Advisory Committee. (The Provincial Department of Health, also a member of the Technical Advisory Committee, did not undertake any mercury monitoring in 1983/84).

Health and Welfare's mercury program in Canada began with a survey of the Indian communities affected by the mercury pollution along the English-Wabigoon River System. They have also conducted general surveys across Canada in 1976/77 and again in 1979/80. Six northern Manitoba communities along or near the diversion route - South Indian Lake, Nelson House, Cross Lake, Norway House, Split Lake, and York Landing - were sampled in 1976, 1979/80, 1981/82. Nelson House was also sampled in 1978. Results of these tests were included in the 1982/83 annual report of this Agreement. The results of the mercury monitoring program for these six communities for 1983/84 are given in Table 4.5.

Table 4.5

Results of the Mercury Monitoring Program
in Six Northern Communities from
July 1, 1983 - October 31, 1984

Communities	Total # Samples	Ranges 0-20 ppb	20+ - 50 ppb	Over 50 ppb	Over 100 ppb
Cross Lake 2079 - 10%	Hair 211 Blood 0	204(97%)	7 (3%)		
Nelson House 1956 - 13%	Hair 229 Blook 34	194 (85%) 34 (100%)	29 (13%)	5 (2%)	1
Norway House 2335 - 10%	Hair 214 Blood 30	210 (98%) 30 (100%)	3 (2%)	1	
South Indian Lake 655 - 14%	Hair 68 Blood 25	49 (72%) 25 (100%)	17 (25%)	2 (3%)	
Split Lake 1037 - 10%	Hair 104 Blood 0	92 (89%)	12 (11%)		
York Landing 425 - 8.5%	Hair 32 Blood 4	26 (81%) 4 (100%)	6 (19%)		
Total Pop. 8489 - 11%	Hair 858 Blood 93	765 (89%) 93 (100%)	50 (6%) -	32 (4%) -	1 -

The blood sampling was discontinued in Norway House as of December 31, 1983. York Landing, Split Lake and Cross Lake were discontinued previously.

NOTE: There was one woman from Nelson House with a mercury level of 150.3 ppb.

CONVERSION: 20 ppb = 6 ppm
50 ppb = 15 ppm
(BLOOD) 100 ppb = 30 ppm (HAIR)

ppb - parts per billions (Blood)

ppm - parts per million (hair)

Of particular interest to this Agreement are the results for those people sampled by Health and Welfare Canada in South Indian Lake and Nelson House (see Table 4.6). In South Indian Lake, in 1976, the majority of people tested (80%) had blood levels in the normal range of 0-20 p.p.b. In 1979 the majority of individuals tested (69%) had slightly elevated mercury levels of 20-100 p.p.b. From June 1981 to June 1983, 89% of the population of South Indian Lake were tested for mercury. The majority tested had mercury levels within the normal range (67% of hair samples and 85% of blood samples).

From July 1, 1983 - October 31, 1984, 14% of the population of South Indian Lake were tested. 100% of the blood samples taken showed values in the normal range of 0-20 p.p.b. 72% of the hair samples showed values in the normal range of 0-20 p.p.b., 25% were in the slightly elevated range of 20-50 p.p.b., and 3% were over 50 p.p.b.

In Nelson House, in 1976, 96% of the people tested were within the normal range of 0-20 p.p.b. In 1978, 68% of those individuals tested had slightly elevated mercury levels of 20-100 p.p.b., and 1 person had a level of over 100 p.p.b. In 1980, 56% had normal levels. In the period June 1981 - June 1983, with 2.7% of the population tested, 87% of the hair samples and 96% of the blood samples showed values within the normal range.

From July 1, 1983 - October 31, 1984, 13% of the population of Nelson House were tested for mercury levels. 100% of the blood samples showed values in the normal range of 0-20 p.p.b. 85% of the hair samples were within the normal range of 0-20 p.p.b., 13% of the values showed slightly elevated levels of 20-50 p.p.b.,m and 2% showed over 50 p.p.b., with one woman having a mercury level of 150.3 p.p.b. This woman will be retested. Neurological testing and nutritional advice will also be provided as required.

Within the six northern Manitoba communities along or near the diversion route, a 100% voluntary testing program was once again offered in 1983/84. That is, anyone living in these communities who wished to be tested for mercury was tested. Hair analysis is the main method used. A small band of hair (about the width of a pencil) is cut close to the scalp from the back of

Table 4.6

Results of the Mercury Monitoring Program
for South Indian Lake and Nelson House,
1976 - 1983

South Indian Lake	Total # Samples	Ranges 0-20 ppb	20+ - 100 ppb	Over 50 ppb	Over 100 ppb
1976	49	39 (80%)	10 (20%)		
1979	103	26 (25%)	71 (69%)		6 (6%)
June 81 - June 83	Hair 505	341 (67%)	164 (33%)	9	
	Blood 74	63 (85%)	11 (15%)	1	
Nelson House					
1976	54	52 (96%)	2 (4%)		
1978	25	7 (28%)	17 (68%)		1 (4%)
1980	132	74 (56%)	58 (44%)		
June 81 - June 83	Hair 30	26 (87%)	4 (13%)		
	Blood 31	30 (96%)	1 (4%)		

Table 4.7

Results of the Mercury Monitoring Program
in Six Northern Communities from
June 30, 1981 - June 30, 1983

Communities	Total # Samples	0-20 ppb	20+ - 100 ppb	Ranges Over 50 ppb
Cross Lake 2079 - 25%	Hair 461 Blood 65	428 (93%) 65 (100%)	33 (7%)	2
Nelson House 1958 - 2.9%	Hair 30 Blood 31	26 (87%) 30 (96%)	4 (13%) 1 (4%)	
Norway House 2335 - 11%	Hair 172 Blood 85	164 (95%) 85 (100%)	8 (5%)	
South Indian Lake 655 - 88%	Hair 505 Blood 74	341 (67%) 63 (85%)	164 (33%) 11 (15%)	9 1
Split Lake 1037 - 40%	Hair 386 Blood 29	333 (86%) 29 (100%	53 (14%)	4
York Landing 425 - 42%	Hair 179 Blood 0*	165 (92%)	14 (8%)	1
Total 8489 - 20% (POPULATION)	Hair 1733 Blood 284	1457 437	287 12	16 1

* There were only 3 births in this community for the sampling period and no blood samples were taken.

NOTE: There were no mercury levels over 100 ppb
Conversion: 20 ppb = 6 ppm
50 ppb = 15 ppm
(BLOOD) 100 ppb = 30 ppm (HAIR)

ppb - parts per billion (BLOOD)

ppm - parts per million (HAIR)

Revised:
June, 1984

the head and sent to the Health and Welfare Canada laboratory in Ottawa for analysis. The hair length is sectioned into 1 cm lengths and analyzed. (A rate of growth of 1 cm/month is assumed). Each individual tested receives the results of his or her test - the highest and lowest mercury levels and the month in which each was recorded. Results are usually received within five - six weeks of testing.

For prenatal women blood samples are taken. They receive their results in two - three weeks. Maternal blood samples and cord blood samples are also taken at the time of delivery.

If an individual's mercury levels are slightly elevated, nutritional advice is given on how to reduce mercury intake in their diet. Those with more elevated mercury levels (greater than 100 ppb) are retested until their mercury levels return to normal. Neurological testing is also given when necessary.

Health and Welfare Canada also undertook mercury monitoring programs in 1983/84 in a number of other Manitoba native communities, namely Brochet, Fox Lake, God's Lake, God's River, Lac Brochet, Little Grand Rapids, Pauingassi, Pukatawagan, Red Sucker Lake, Shamattawa, and Tadoule Lake.

The direction for 1984/85 is that of offering the mercury hair sampling monitoring program to the residents of 28 communities which would again include a 100% voluntary program in South Indian Lake, Nelson House, Norway House, Cross Lake, Split Lake, and York Landing.

According to the World Health Organization, the 5 most sensitive people out of every 100 would start to show symptoms of mercury poisoning at the 200-500 ppb range. The mercury testing done by Health and Welfare has shown no evidence of mercury poisoning in the individuals tested in any Manitoba community including those along the Churchill River Diversion route.

In the 1976/77 survey conducted by Health and Welfare Canada questions were asked regarding the fish eating habits of the people who were tested for mercury. From that survey it is generally known that people with elevated mercury levels are heavy fish eaters. However, the fish eating habits of those people with low mercury levels were not determined.

CHAPTER 5. PROGRAM 4

5.1 Project 4.1 Public Awarness

In September 1983, the Agreement Coordinator was appointed as the project leader for the public awareness program. As 1983/84 was the first year that this program was active under the Agreement, determining the basic components of this program was the first priority (eg. identification of the target audience, selection of the most effective public awareness methods for this audience, etc.).

The residents of the communities of South Indian Lake and Nelson House were selected as the main target audience for two principal reasons. These two communities are located in the geographic study area of the Agreement. Secondly, the residents of Nelson House and South Indian Lake have a particularly strong interrelationship with their immediate environment through their pursuits of fishing and trapping. In particular, many residents are dependent on fish as a source of income and/or as the major source of their dietary protein.

A secondary target audience was also identified. This group includes any individual or organization with a special interest in mercury in the study area of the Agreement. Included in this group are the City of Thompson; the Northern Flood Committee; native organizations, such as the First Nations Confederacy; special interest groups such as the Manitoba Naturalist Society; and other organizations interested in mercury in this area, from medical organizations, such as the Northern Nursing Education Program to the various federal and provincial grovernment departments.

Efforts were then directed at determining the most effective means to inform the main target audience about the progress of the Agreement. A number of different means of communication were considered, including public meetings, posters, newsletters, videotapes, school programs, pamphlets and press releases.

A press release was issued at the time of the signing of the Agreement. An informal information meeting was held with the Northern Flood Committee in November 1983. Two articles appeared in the Department of Northern Affairs newsletter; one summarized the important components of the Agreement such as its objectives and budget, and the other article briefly highlighted the major findings of the projects as of April 1, 1984.

A major effort was directed at scheduling a public meeting on mercury in Nelson House. Efforts were made to attract as large an audience to such a meeting as possible. These included scheduling the meeting at a date selected by the community, advertising the meeting by posters and radio announcements in English and Cree, obtaining the services of an English-Cree translator for the entire meeting, and the provision of free refreshments. On three or four occasions a date was selected by the community (between November 83 and April 84) and subsequently cancelled at the community's request. As a result no public meeting was held in 1983/84.

The first annual report of the Agreement was given a wide public distribution in order to inform the members of the secondary target audience, as well as the main target audience, of the progress of the Agreement. Copies were also sent to various media organizations in Manitoba.

Plans for the 1984/85 program include scheduling public meetings in Nelson House and South Indian Lake, the preparation of additional articles in the northern newsletters, more meetings with the Northern Flood Committee, preparation of a videotape on mercury, and the preparation of material on mercury for use in the schools in South Indian Lake and Nelson House.

5.2 Other Program 4 Projects

Two other projects are identified in Program 4, namely: Project 4.2, Study Coordination and Management, and Project 4.3 Study Report.
Under Project 4.2, Ms. L. McKerness was hired as the Agreement Coordinator effective June 27, 1983. Project 4.3 will only be undertaken in 1985/86, the final year of the agreement.

GLOSSARY

AEROBIC - living or active in the presence of free oxygen.

AMBIENT - the surrounding or encompassing environment. Ambient air conditions usually refers to those conditions removed from major sources of contaminants.

ANAEROBIC - living or active in the absence of free oxygen.

BENTHIC - pertaining to, or relating to BENTHOS.

BENTHOS - ORGANISMS that live on or in the bottom of bodies of water.

BIOACCUMULATION - the increasing concentration of a substance (eg MERCURY) up the food chain (eg. from invertebrates, such as ZOOPLANKTON, to fish, to people).

BIVALENT - capable of combining with 2 atoms of hydrogen or their equivalent.

CHIRONOMID - common name is midge (a small insect).

CORRELATION COEFFICIENT - a measure of the CORRELATION between two variables, X and Y.

CORRELATION - the study of the simultaneous variation of two or more variables. If one variable (eg. mercury concentration) increases as the other increases (eg fish size) and decreases as the other decreases, there is said to be a positive correlation.

DEMETHYLATION - conversion of one type of chemical compound into another by the removal of the methyl group (CH_3-). The reverse of methylation.

ECOLOGY - a branch of science concerned with the interrelationship of ORGANISMS and their environment especially as manifested by natural cycles and rhythms, community development and structure, interaction between different kinds of ORGANISMS, geographic distribution, and population alterations.

ECOSYSTEM - an ecological community considered together with the nonliving factors of the environment as a unit.

ECOLOGICAL SUCCESSION - an orderly process of ECOSYSTEM development that involves changes in species structure and community processes with time.

FAUNA - the animal life of an area.

GANG NETS - a continuous length of GILL NET which consists of segments of different mesh sizes. The Department of Natural Resources uses a gang net consisting of panels of 1 1/2", 2", 3", 3 3/4", 4 1/4", and 5" of stretched mesh nylon. The Department of Fisheries and Oceans uses a gang net for their fish surveys consisting of panels of 3 1/2", 4 1/4", and 5 1/4" of stretched mesh nylon.

GILL NETS - a fishing net which entangles the fish by the gills.

HALF LIFE - the length of time required for the mercury concentration to be reduced by half, assuming no additional intake of mercury.

INORGANIC - not organic, not containing carbon or compounds of carbon (with a few exceptions).

INVERTEBRATE - lacking a backbone or spinal column.

ION - an electrically charged atom or group of atoms.

LIMNOCORRALS - enclosed experimental ECOSYSTEMS which are submerged and anchored in a body of water. The limnocorrals used in Project 2.1 were approximately 10 meters in diameter and 3-4 meters deep.

LIMNOLOGICAL PARAMETERS - various limnological characteristics such as oxygen concentration, pH, temperature, turbidity, species type and population, etc.

LIMNOLOGY - the scientific study of the physical, chemical, and biological conditions of fresh water, especially ponds and lakes.

MERCURY - a naturally occurring chemical element. It can exist in three different forms: as the pure element, a silver-white liquid used in thermometers; in an inorganic form, such as mercuric sulfide (HgS) found in bedrock; and in an organic form, such as methyl mercury (CH_3Hg-) found in fish.

METAL BINDING MINERAL COLLID - an INORGANIC mixture which can take up and hold metals (eg. mercury) by chemical forces.

METHANE BACTERIA - ANAERODIC bacteria which produce methane.

METHYLATED - see METHYLATION

METHYLATION - conversion of one type of chemical compound into another by the addition or incorporation of the methyl group (CH_3-) e.g. conversion of inorganic mercury to METHYL-MERCURY.

METHYL-MERCURY - an ORGANIC form of mercury, containing the methyl group (CH_3-), which has a high affinity for animal tissue and is concentrated up the food chain.

MICROBES - very minute OGANISMS.

MICROBIAL - pertaining to MICROBES.

MICROGRAM µg - one millionth of a gram (.000001 gram or 1×10^{-6} gram).

NUTRIENT - any substance which promotes growth or provides energy for a living ORGANISM.

ORGANIC - relating to or derived from living ORGANISMS.

ORGANISM - a living being.

pH - a measure of the acidity or alkalinity of a liquid. pH values can range from 0 (highly acidic) to 14 (highly alkaline) with a pH reading of 7 indicating a neutral solution.

PLANKTON - the passively floating or weakly swimming animal and plant life of a body of water consisting chiefly of minute plants and of minute animals that have only weak powers of movement.

p.p.m. - PARTS PER MILLION - one millionth of any measure (eg. 1 minute in 2 years or 2 drops of oil in a 45 gal drum of gas).

RADIOACTIVE ISOTOPE - natural or artificial ISOTOPE exhibiting radioactivity. A radioactive isotope of mercury is used in Project 2.1 to provide a method for following the movement of mercury through the food chain.

REDOX - abbreviation for reduction - oxidation. When a substance gains one or more electrons it is said to have been reduced. If the substance loses one or more electrons, it is said to have been oxidized.

REDUCING - see REDOX

ISOTOPE - one of a set of chemically identical types of atom which have the same atomic number but different mass numbers.

REGRESSION ANALYSIS - a relationship between two or more CORRELATED variables that is often determined from data and is used especially to predict values of one variable when given values of the others.

SPECIES - a basic TAXONOMIC group consisting of a group of individuals of common ancestry which closely resemble each other and can interbreed producing fertile offspring.

SUBSTRATE - NUTRIENT medium for bacteria.

SYNERGISTIC - see SYNERGISM

SYNERGISM - the total effect of an interaction of two or more substances that exceeds the sum of the effects of each substance separately.

TAXONOMIC - pertaining to TAXONOMY.

TAXONOMY - the arrangement of animals and plants into groups based on their natural relationships.

TURBIDITY - a measure of the muddiness of the water.

ZOOPLANKTON - animal life of the PLANKTON.

CANADA-MANITOBA AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

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CANADA-MANITOBA AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

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CANADA-MANITOBA AGREEMENT ON THE STUDY AND MONITORING OF MERCURY IN THE CHURCHILL RIVER DIVERSION

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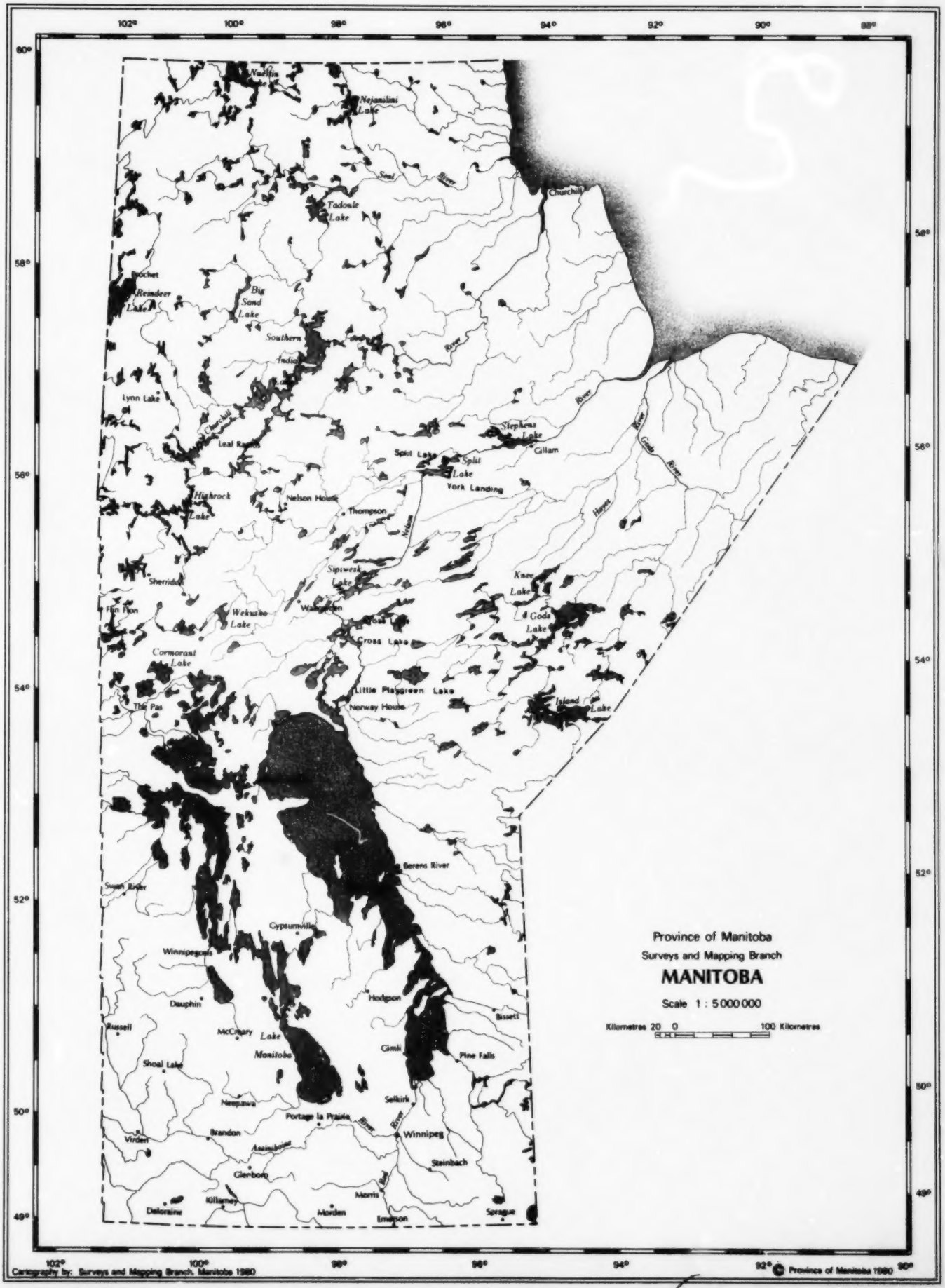
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Surveys and Mapping Branch
MANITOBA
Scale 1 : 5 000 000
Kilometres 20 0 100 Kilometres
Cartography by: Surveys and Mapping Branch, Manitoba 1980
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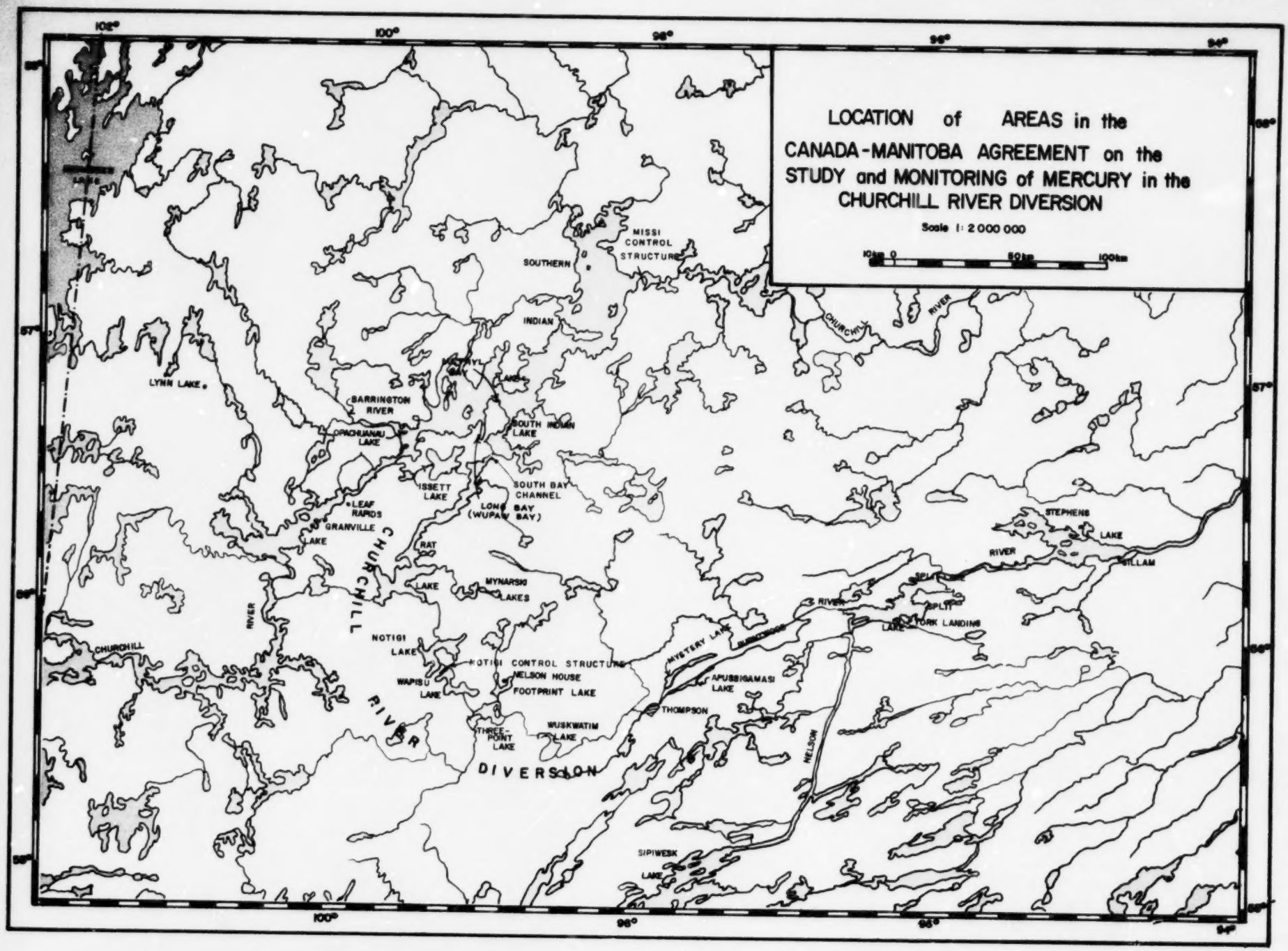
Churchill
Nejanilini Lake
Tadoule Lake
Reindeer Lake
Big Sand Lake
Southern Indian Lake
Lynn Lake
Leaf Rapids
Stephens Lake
Gillam
Split Lake
York Landing
Nelson House
Thompson
Hudson Hope
Sherridon
Wekusko Lake
Wabowden
Cross Lake
Knee Lake
4 Gods Lake
Cormorant Lake
Little Playgreen Lake
Norway House
The Pas
Island Lake
Berens River
Sweet Grass
Gypsumville
Winnipegosis
Dauphin
Hodgson
Bissett
Russell
McCreary
Lake Manitoba
Gimli
Pine Falls
Shoal Lake
Neepawa
Selkirk
Portage la Prairie
Brandon
Virden
Winnipeg
Steinbach
Glenboro
Morris
Killarney
Deloraine
Morden
Emerson
Sprague


LOCATION of AREAS in the
CANADA-MANITOBA AGREEMENT on the
STUDY and MONITORING of MERCURY in the
CHURCHILL RIVER DIVERSION
Scale 1: 2 000 000
0 50km 100km
102°
100°
98°
96°
94°
58°
57°
56°
55°
LYNN LAKE
BARRINGTON RIVER
OPACHUANAU LAKE
ISSETT LAKE
LEAF RAPIDS
GRANVILLE LAKE
RAT LAKE
MYNARSKI LAKES
SOUTH INDIAN LAKE
SOUTH BAY CHANNEL
LONG BAY (WUPAW BAY)
SOUTHERN INDIAN LAKE
MISSI CONTROL STRUCTURE
CHURCHILL RIVER
STEPHENS LAKE
SPLIT LAKE
YORK LANDING
NOTIGI LAKE
NOTIGI CONTROL STRUCTURE
NELSON HOUSE
WAPISU LAKE
FOOTPRINT LAKE
THREE POINT LAKE
WUSKWATIM LAKE
MYSTERY LAKE
APUSSIGAMASI LAKE
THOMPSON
NELSON RIVER
CHURCHILL
SIPIWESK LAKE
DIVERSION